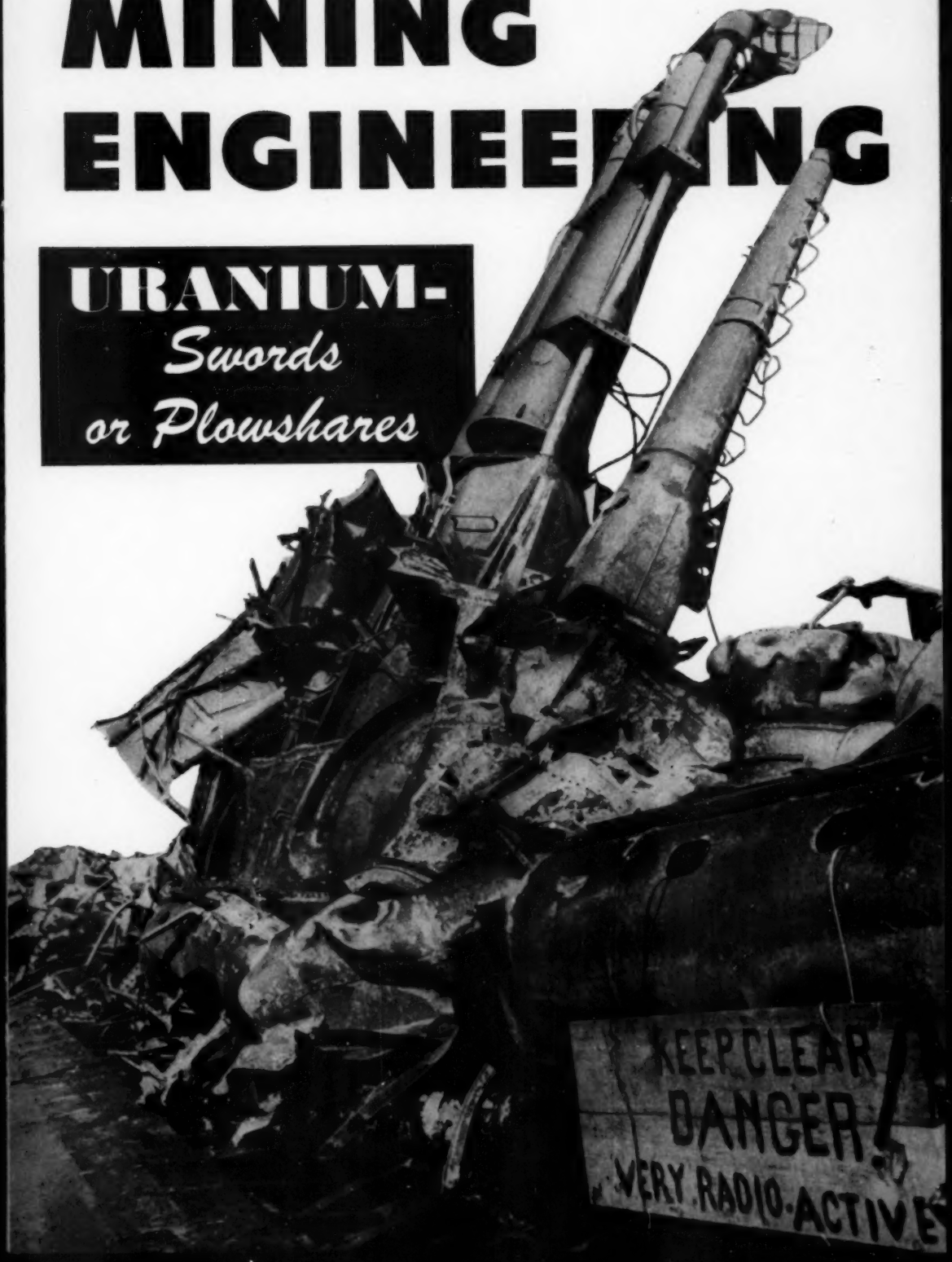
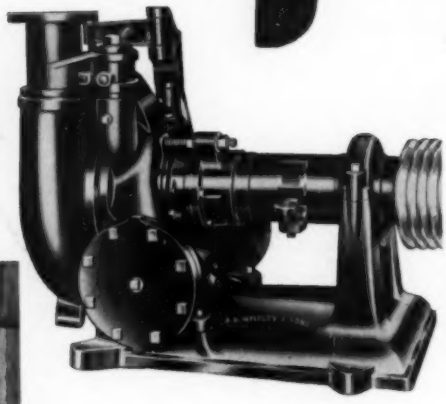
MINING ENGINEERING

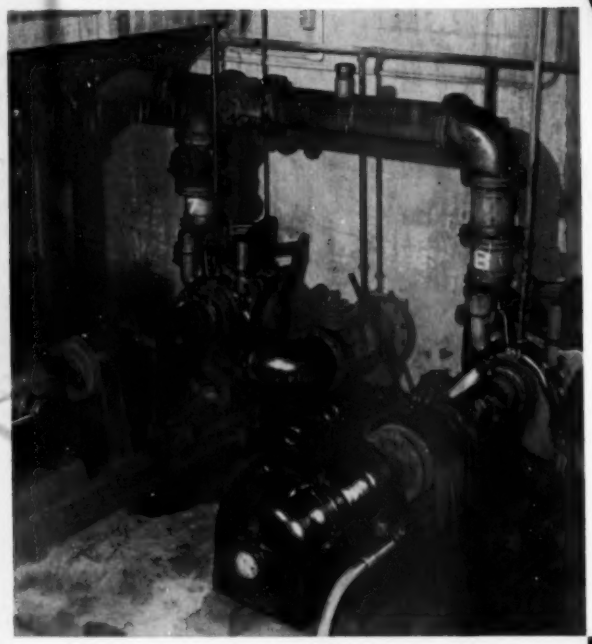
URANIUM- *Swords or Plowshares*



middlings

WILFLEY centrifugal PUMPS





This installation of Model "K" WILFLEY pumps handles middlings in a modern copper mill in Mexico. The pumps operate continuously on a 24-hour, trouble-free schedule. The Model "K" is a companion to the famous WILFLEY Acid Pump.

Important mechanical improvements and refinements in the new Model "K" WILFLEY Sand Pumps save power and production dollars—deliver stepped-up 24-hour-a-day performance and low cost operation. These pumps are noted for efficiency and economy in handling sands, slimes, sludges and slurries. Easy interchangeability of wear parts. Low maintenance. Continuous, 24-hour operation without attention. Individual engineering on every application. Write or wire for Model "K" Bulletin 200.

A. R. WILFLEY & SONS, INC., Denver, Colorado, U.S.A.
New York Office: 1775 Broadway, New York City

Buy **WILFLEY** *for Cost-Saving Performance*

MINING ENGINEERING

Incorporating Mining and Metallurgy, Mining Technology and Coal Technology

VOL. 3 NO. 9 SEPTEMBER, 1951

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FEATURES

Reporter 759
Editorial: Coffee and The Boss 761
Trends 756
Mining News 809
AIME News 811
Coming Events 818
Manufacturers' News 746
Meet the Authors 754
Books 776

ARTICLES

Uranium—Swords or Plowshares 762
Open-Pit Forum—Modern Equipment Cuts Costs at Bagdad 767
Employee Training 768
Wire Rope 772

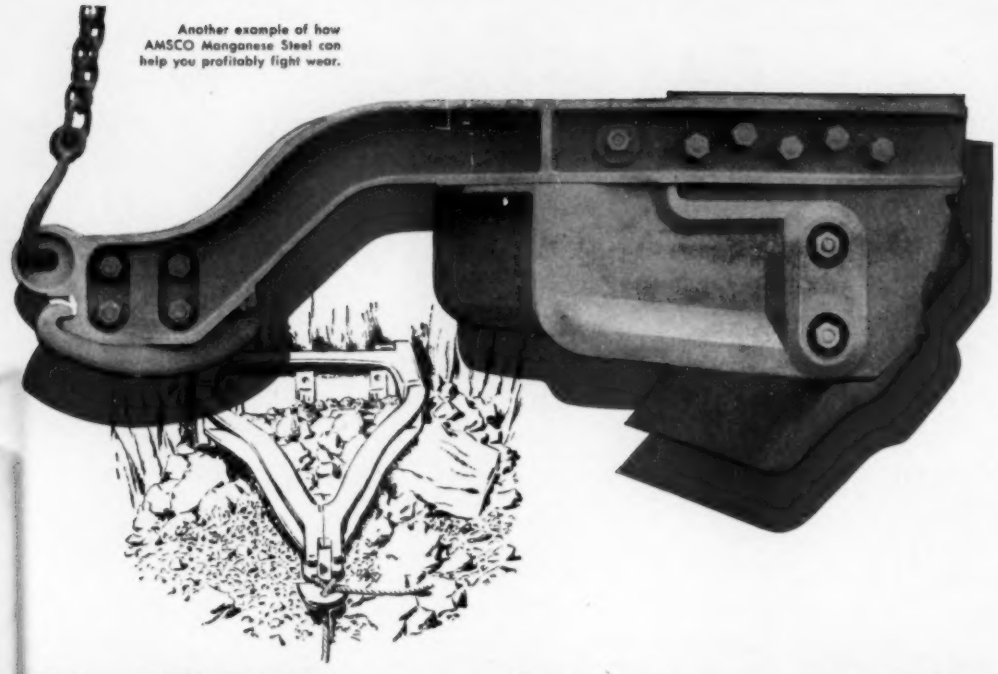
TRANSACTIONS

Developing Mesabi Orebodies Under Lake Beds 777
Adsorption of Silver Ion by Sphalerite 780
A Graphic Statistical History of the Joplin or Tri-State Lead-Zinc District 785
Flotation Rates and Flotation Efficiency 791
Magnetic and Chemical Analyses of Ores and Mill Products Containing Magnetite and Ilmenite 797
Characteristics of Mechanized Mining Sections 803

Personnel Service *742*
Professional Services *818*
Advertisers Index *820*

COVER: Submarine USS Skate, damaged and radioactive after the Bikini "Able" explosion. This is typical of the effectiveness of the new atomic weapons but the world can expect more of atomic energy than sunken hulks and devastated cities as told in the article "Uranium — Swords or Plowshares" on page 762.

Another example of how AMSCO Manganese Steel can help you profitably fight wear.



This SCRAPER cut maintenance costs 20%!

How AMSCO Manganese Steel proved tougher than a tough mining problem

One of the toughest mining operations you'll find anywhere—tough from the standpoint of how it punishes equipment—is scraping heavy, corrosive pyrite ore. For example, a California mine has a deposit of 98% pure pyrite—with a specific gravity of 4.8. Impacts and abrasion caused by this ore were making short work of the scrapers previously used . . . on the average they needed major repairs over 4 times per year.

Several years ago two scrapers of the type shown above, which are sold exclusively by Joy Manufacturing Co., were put in service. They were made entirely of AMSCO Manganese Steel, and since then they've mined *over 220,000 tons of pyrite ore — and they're still in excellent condition!* These scrapers are repaired only once a year; simple repairs involving relipping and hardfacing of wearing surfaces.

Obviously, not all mining or excavating operations are as equipment-punishing as this one . . . *but the moral is clear . . .*

WHEREVER YOU MEET A PROBLEM OF WEAR CAUSED BY IMPACT AND/OR ABRASION . . .

. . . find out about longer-lasting, dollar-saving Manganese Steel made by AMSCO . . . world's largest producer of Manganese Steel castings for all industry.

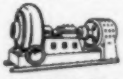
AMSCO controls impact and abrasive wear in 5 basic industrial operations:

Power Transmission

Mining and Excavating

Transportation

Crushing and Pulverizing



Materials Handling

Brake Shoe **AMERICAN MANGANESE STEEL DIVISION**

417 EAST 14th STREET • CHICAGO HEIGHTS, ILL.

Other Plants: New Castle, Del., Denver, Oakland, Cal., Los Angeles, St. Louis. In Canada: Joliette Steel Division, Joliette, Que. Amsco Welding Products distributed in Canada by Canadian Liquid Air Co., Ltd.

Performance pays . . .

Mill operators are judged by results. For the man who must be shown, here are some more actual test figures.

Case No. 7

Tests at a mining operation grinding sulphide copper ore.

Service: Marcy 6′ × 4½′ ball mills grinding a high sulphide ore from minus ¾″ to minus 14 mesh. Balls charged were 5″ dia.

Comparison: For many years the company used austenitic manganese steel liners in its mills. Then a change was made to high carbon chromium-molybdenum steel liners, normalized and tempered to 360 Brinell.

Liner type: Shell (barrel) liners, wave type.

Results:	Tonnage ground
Austenitic manganese steel (average)	75,000
Cr-Mo steel (average)	84,000

Case No. 8

Tests at a mining operation grinding gold-bearing quartz ore.

Service: Marcy 6′ × 7′ overflow type mill grinding ¾″ feed.

Comparison: One set of manganese steel liners was run till worn out, and followed by one set of high carbon chromium-molybdenum steel liners run under similar conditions.

Liner type: Shell (barrel) liners, wave type.

Results:	Life—Days	Tonnage Ground
Manganese steel liners	148	48,932
Cr-Mo steel liners	212	74,794

The chrome-molybdenum steel liners showed an increased tonnage ground of 53%.

Write for 32 pp reprint of an informative paper published by the Amer. Inst. of Mining and Metallurgical Engrs., giving results of wear tests on grinding ball materials—FREE!

Climax Molybdenum Company

500 Fifth Avenue · New York City

Please send your FREE Reprint on "Wear Tests"

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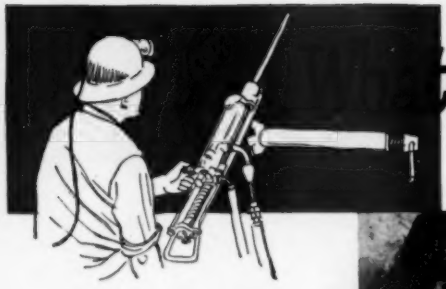
MOLY

MIE9

t's ahead for you?



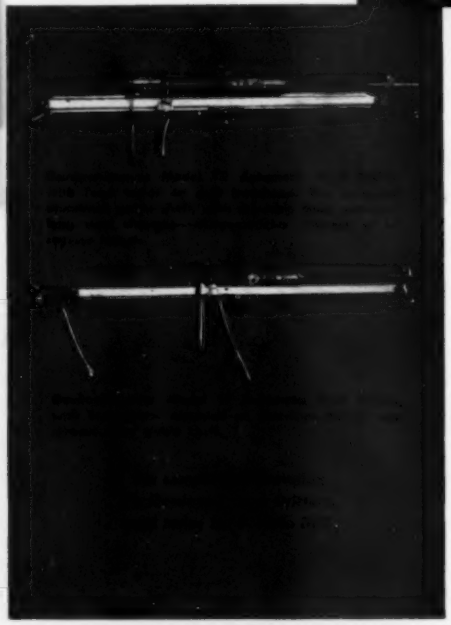
Increased demands
for ore production
from your mine?

A stepped-up
development program
to reach your ore reserves?

Hard rock you've got to
"hole through" in a hurry?

A program
to hold down
production costs?

Gardner-Denver CF89H
Automatic Feed Drifters.



For help in solving mining problems such as these, choose famous Gardner-Denver Automatic Feed Drifters. They're designed by men who know what it takes to do a fast, low-cost drilling job underground.

The Gardner-Denver self-adjusting feed, for example, responds automatically to bit penetration — is automatically regulated by the type of ground being drilled. Maximum drilling speed is easily maintained—"green" miners drill almost as fast as "old-timers." The long-wearing, "slow-motion" piston feed motor is economical to operate, too—uses only 3% to 5% of the total air consumption of the drill.

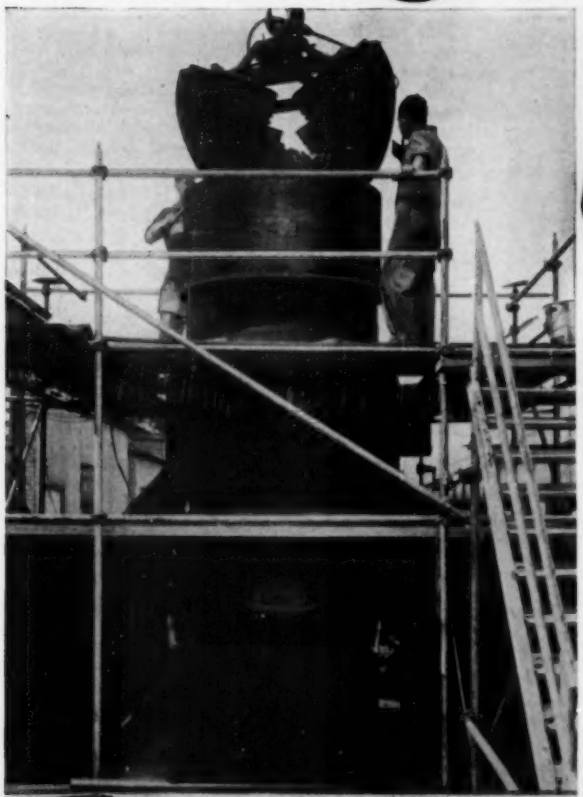
SINCE 1859

GARDNER-DENVER

Gardner-Denver Company, Quincy, Illinois
In Canada: Gardner-Denver Company (Canada), Ltd., Toronto, Ontario

THE QUALITY LEADER IN COMPRESSORS, PUMPS AND ROCK DRILLS

WILL YOUR CRUSHER MEET THIS Strength Test?



Oscillograph readings of strain on *Hydrocone* crusher were made at various points on the topshell spider, topshell, bottomshell and bottom plate. Test was made in A-C Processing Machinery laboratory by Allis-Chalmers engineers.

IN A SPECIAL TEST, the actual stress on various parts of a *Hydrocone* crusher was measured with an oscillograph. This stress analysis showed that strain on the crusher did not exceed 4000 psi at any point — even though hard taconite ore was being crushed.

The test indicated, too, how well various elements of the *Hydrocone* crusher are proportioned for high strength — vital to long life and low maintenance!

NO DEAD WEIGHT

All weight in the *Hydrocone* crusher is concentrated into resisting the crushing force. Top and bottom shell, eccentric and spider cap are of cast steel construction. The short, heavy mainshaft is annealed forged steel. Mantle and concaves are of a special steel.

Hydraulic *Speed-Set* control enables the operator to change product size quickly and easily. Automatic Reset provides hydraulic protection from tramp iron.

More facts about the *Hydrocone* crusher can be obtained from the A-C representative in your area, or by writing for *Hydrocone* crusher Bulletin 07B7145B. Allis-Chalmers, Milwaukee 1, Wis.

A-3487

Hydrocone and *Speed-Set* are Allis-Chalmers trademarks.

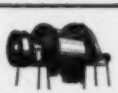
ALLIS-CHALMERS

Sales Offices in Principal Cities in the U. S. A. Distributors Throughout the World.

Pulverators

Vibrating Screens

Jaw Crushers



Grinding Mills

Gyratory Crushers

Kilns, Coolers, Dryers

Personnel Service

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York Office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Economic Geologist, 33, married, Ph.D. in geology. Experience includes teaching, mining geology, exploration, and areal geology. Desires to enter technical sales with company dealing with minerals or metals in New York area. M-636.

Mining Engineer, 33, married, B.S. mining engineering. Experience includes underground and open-pit mines, copper concentrator, sales engineering, and construction. Desire permanent position in mining research and development, administrative mining engineering or ore purchasing. Available thirty days. Prefer southern California. M-637-4912-E-8-San Francisco.

Geologist, 24, single. Recent graduate University of New Hampshire. B.S. geology. Available immediately for domestic or foreign employment. M-640.

Geologist, 27, recent graduate with engineering background, desires training work with progressive company. Now unemployed. Prefer midwest but will consider other areas. M-641.

POSITIONS OPEN

Assistant to Vice-President, 36 to 45; must have mining operations background and should be particularly experienced in purchasing mining equipment, and warehousing and traffic for mining operations. Knowledge of Spanish desirable. Salary, $15,000 a year. Headquarters, New York. Y5823.

Mine Superintendent, not over 50, for iron ore mining operation; open stope; must know rick as the work will be done by upraising. Must have a good record of handling labor. The mine is one being reopened. Salary, $6000 to $8400 a year. Location, eastern United States. Y5773.

Mine Manager, technical graduate, with at least 20 years' experience; five of which should have been in responsible operating positions, to take charge of development, construction and training of personnel for a 3000 ton mine in Greece. Experience in mining thick highly inclined seams in soft ground by top slicing or sub-level caving desirable. Two year contract. Salary open. Y5764.

Concentrator Superintendent for mill with 100 tons per hr iron ore capacity. Must have had previous experience and be familiar with magnetic separators and tables, etc. Salary open. Location, eastern United States. Y5754.

Assistant Superintendent, mining engineer, 40 to 50, experienced in mechanical mining methods, maintenance, coal washing, industrial relations for a bituminous coal mine. Location, western Pennsylvania. Y5747.

Assistant Government Mineralogist with degree from recognized university, with post graduate degree in geology, and four years' experience in geological survey work, to undertake geological survey, investigation of mineral deposits, and water supply investigations. Location, Ceylon. Y5717.

Mining Geologist with Master's degree or equivalent, and minimum of seven years' experience, to supervise geologic studies, diamond drill program, and usual responsibilities in independent geology dept. in large underground mine. Salary open. Location, western state. Y5711.

Geologist, 30 to 40, M.S. degree or equivalent in experience and training. Salary open. Location, central states. Y5710.

Mining Engineer, young, to take charge of a tungsten mine. Should have about three years' mining experience. Must speak Spanish. Work will consist of doing some repair work on two shafts, checking up on power machinery and dewatering. The mine will later be rebuilt and placed in operation. Housing available. Salary, $5400 to $6000 a year. Transportation paid. Location, Cuba. Y5522.

Instructor in mining engineering, to teach mine plant design, mine valuation, mine ventilation, mine surveying, and coal mining methods. Position starts fall term. Location, Alaska. Y5470.

POSITION WANTED

MINING ENGINEER, 37, experience operation, examination, mineral economics, raw material problems, U. S. and foreign, seeks connection where reliability, resourcefulness count.

Box H-18 MINING ENGINEERING

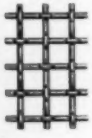
Roof Bolting Costs Less...Lasts Longer

• Roof bolting is accepted as improved practice in coal mines and is now under test in metal mines with apparent success. Already demonstrated are these advantages over timbering: improved efficiency, increased production, lower cost, greater safety, assured permanence, better clearance at walls and roof.

CF&I offers roof bolts with flame-cut slots and serrated wedges. Test them; see how they meet your particular conditions.

In this typical lead-zinc mine, these roof bolts held while timber supports failed in similar service in the same mine.

CF&I Forged Steel Grinding Balls and Rods.



Cal-Wic screens, from filter cloth to 6-inch space cloth.

THE CALIFORNIA WIRE CLOTH CORP., OAKLAND
THE COLORADO FUEL & IRON CORP., DENVER
WICKWIRE SPENCER STEEL DIVISION, NEW YORK

MINE ROOF SUPPORT BOLTS

THE COLORADO FUEL & IRON CORPORATION CF&I

NEW SEPARATOR
Cuts Tailings Losses

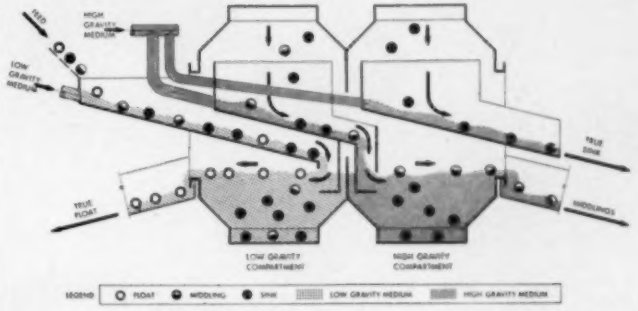
Improved two-stage separation equipment brings new standards of control to Heavy-Media Separation.

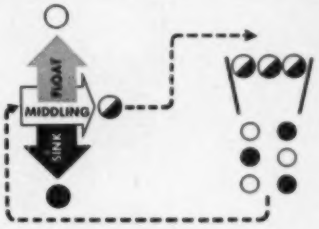
Substantial reductions in tailings losses with significant upgrading of the valuable product are gained by accurate gravity control in the new WEMCO Two-Compartment Drum Separator. Incorporated in the WEMCO Mobil-Mill, the improved separator represents an important advance in Heavy-Media Separation techniques.

Three distinct materials are produced by the WEMCO unit: (1) a true float product, (2) a true sink material, and (3) a middling which may be re-crushed and recycled to the separator for recovery of the valuable fraction.

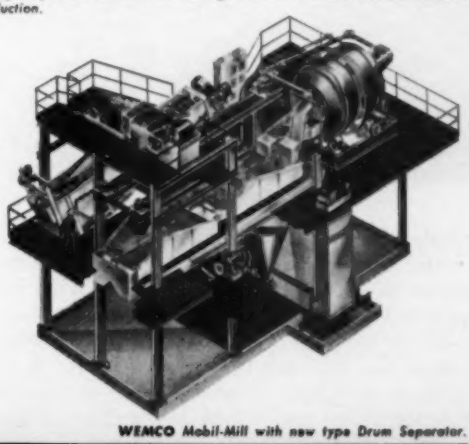
Since only the middling is re-crushed, increased capacity without costly duplication of equipment or increased floor space results. Investment and operating costs are lower per ton of valuable product and media losses are kept to a minimum by the efficient design of this new WEMCO Two-Compartment Separator.

Inquiries for further information should be directed to the manufacturer.





Illustrating **WEMCO'S** *method of producing 3 products in a single separatory vessel by accurate control of heavy medium. Middling is re-cycled through separator to decrease tailings and to increase valuable mineral production.*

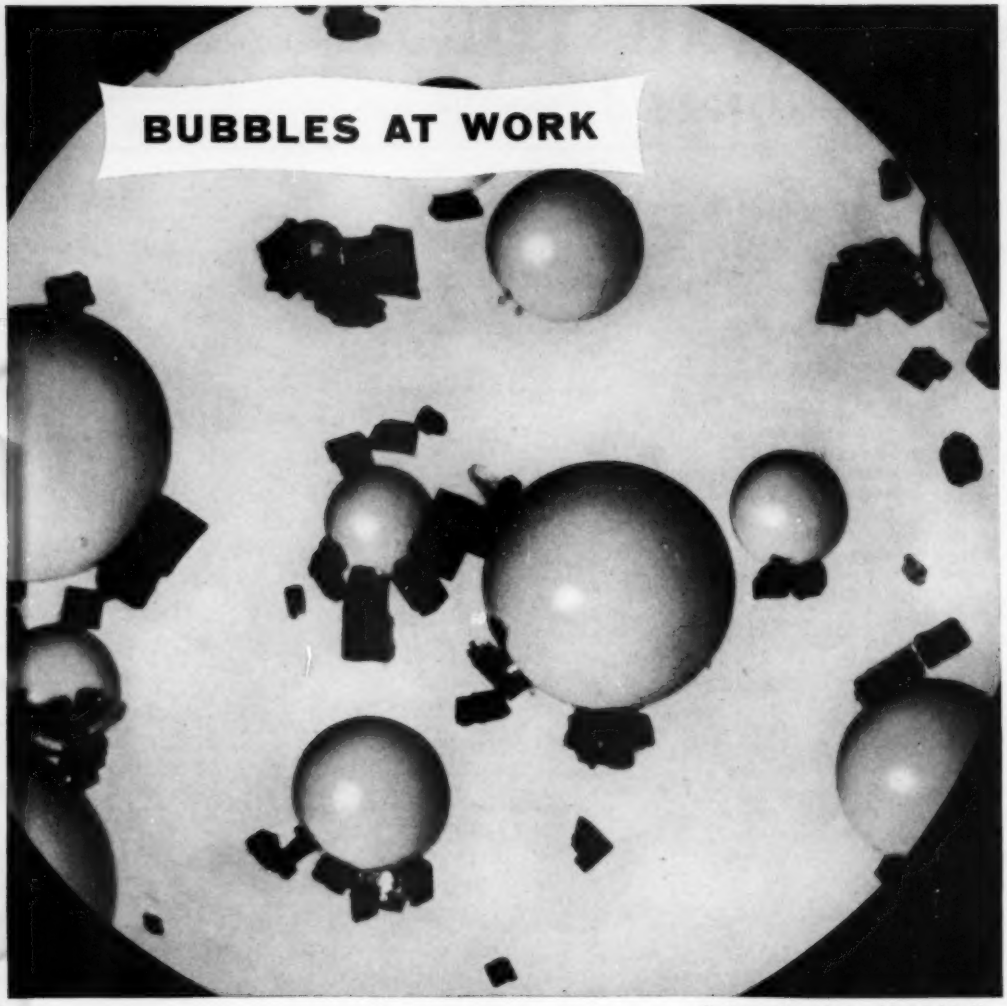


WEMCO *Mobil-Mill with new type Drum Separator.*

OTHER WEMCO PRODUCTS

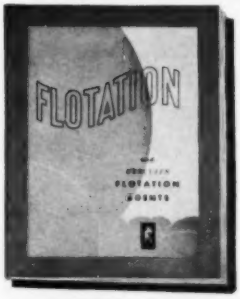
Mobil-Mills • Cool Spirals • HMS Thickeners
HMS Pumps • Densifiers • Cone Separators
Drum Separators • Fagergren & Steffensen Flotation Machines • Fagergren Laboratory Units
Hydroseparators • HMS Laboratory Units
Dewatering Spirals • Agitators • S-H Classifiers
Thickeners • Sand Pumps • Conditioners

WEMCO
WESTERN MACHINERY COMPANY
760-766 FOLSOM STREET SAN FRANCISCO 7 CALIFORNIA



Photomicrograph, greatly enlarged, by H. Rush Spedden

To help step-up flotation recoveries at low cost, Hercules has developed a number of frothers and collectors. Yarmor® F Pine Oil has been a standard of quality among pine oil frothers since the early 1920's. RADA (Hercules' Rosin Amine D Acetate) is a siliceous mineral collector that has good solubility and is easy to handle. It is used in the commercial flotation of several nonmetallic ores. These and other Hercules products are described in a 16-page technical booklet, "Flotation and Hercules Flotation Agents." This booklet also contains many formulas useful in the operation and control of modern ore-dressing mills. *Send for your copy.*



HERCULES POWDER COMPANY 955 King St., Wilmington, Delaware

HERCULES Flotation Agents

NM51-1

Steel

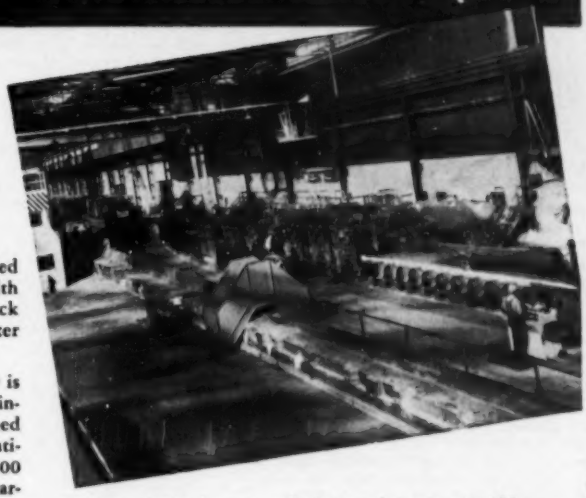
Vulnerable to Socialistic Rust!

Urged on and on by the incentives afforded by our free enterprise system—Americans, with the private money of thousands of stock holders, have built a Bulwark of Steel greater than all the rest of the world.

The capacity of America's steel industry is so great that in 24 hours, it can turn out ingots and castings sufficient to provide finished steel for—500 airplanes, 500 tanks, 1,000 anti-aircraft guns, a half million 3-inch shells, 1,000 howitzers, 2,000 aerial bombs, 1 aircraft carrier, 2 heavy cruisers, two cargo ships, two tankers, 1,000 freight cars, 2,000 trucks, 12,000 automobiles, 20,000 refrigerators, 20,000 stoves, 2,000 homes, and still have 23,000 tons of steel for other purposes.

Remove the incentives of free enterprise or burden it with excessive restrictions and our magnificent steel industry will be vulnerable to the wasting erosion of socialistic rust.

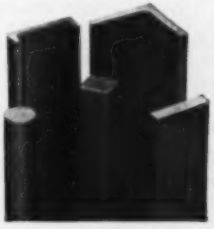
SHEFFIELD
STEEL
CORPORATION
HOUSTON KANSAS CITY
TULSA
SUBSIDIARY OF ARMCO STEEL CORPORATION



Most Modern of Merchant Mills

On this highly mechanized 12-inch merchant mill, steel billets are more efficiently rolled into a wide variety of merchant shapes and sizes vital to manufacturing.

It is a typical example of the continuing modernization and expansion program of Sheffield Steel which, in the last ten years alone, has more than tripled the at-home steel making capacity of Sheffield Steel mills. New furnace and blooming mill capacity now under construction will enable Sheffield Steel to continue to pace industrial progress with an ever increasing supply of steel—the vitamin A of industrial growth.



SHEFFIELD
MERCHANT STEEL

There are few industries that do not use merchant steel. Sheffield Steel mills roll a wide variety of bars and shapes.

SHEFFIELD
MOLY-COP
TRADEMARK REG.
COPPER-MOLYBDENUM-ALLOY
Grinding Balls

USED AND PROVED ALL AROUND THE WORLD

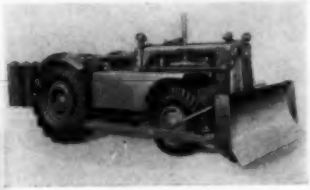
Sheffield Products: Carbon and Alloy Steel, Ingots, Blooms, Billets, Plates, Sheets, Hot Rolled Bars, Steel Joists, Structural Shapes, Reinforcing Bars, Welded Wire Mesh, Wire Products, Wire Rods, Fence, Spring Wire, Nails, Rivets, Grinding Media, Forgings, Track Spikes, Bolt and Nut Products

Export Representative: ARMCO INTERNATIONAL CORPORATION • Middletown, Ohio

MORE SCRAP MEANS MORE STEEL • TURN YOURS IN TODAY!

Straight-Blade Dozer

A straight blade bulldozing machine for use with the company's line of DWIO tractors, is now being manufactured by *Caterpillar Tractor Co.* Similar in design to other Caterpillar bulldozers, the components of



the No. 10S bulldozer include the blade, push arms and braces, hitch, sheave support and heavy-duty radiator guard, combination cable and sheave group. The trunnions for the new bulldozer model are included in the weight box and frame group which differs widely from the company's track-type tractors. This group is a substantial assembly, fabricated of heavy structural steel plate mounted in conjunction with the Caterpillar DWIO Tractor frame. The heavy-duty weight box and frame group not only provides support for the bulldozer trunnions at each side of the tractor, but includes a heavy box at the rear of the tractor to accommodate four counterweights. The counterweight box is designed with a towing hitch, so that the tractor can also be used for drawbar purposes. **Circle No. 1**

Air Grinder

A new air grinder, announced by *Ingersoll-Rand* has an added safety device designed to prevent overspeed operation and possible accidents. It has special application in foundries, steel mills, and metal-working plants where hand grinding is required for snagging, trimming, smoothing, etc. The new grinder contains a motor governor to maintain correct wheel speed, plus a built-in unit called the overspeed safety coupling. In case the motor overspeeds because of governor wear, abuse, maladjustment or dirty air, the overspeed safety coupling automatically uncouples the arbor and the grinding wheel from the motor, making it impossible to operate the grinder until the cause of overspeeding has been corrected. Replacement, if needed, is inexpensive and no lapping is necessary. Other construction features provide 20 pct more power and lighter weight than previous models. **Circle No. 2**

Self Resucer

The compact, lightweight self resucer protects the wearer for 30 min in carbon monoxide concentration found after fires or explosions in mines. The wearer merely lifts a sealing arm at the back of the unit to pry the lid up revealing a plunger. The cartridge is filled with Hopcalite and a drying agent. The Hopcalite oxidizes poisonous carbon monoxide to harmless carbon dioxide and thus protection is given the wearer so that he can reach fresh air safely. An adjustable neckband supports the unit in place. This new Self-Resucer has been developed by *Mine Safety Appliance Co.* **Circle No. 3**

Hoist-Binder

The new Hoist-Binder, announced by *Coffing Hoist Co.* works on the ratchet hoist principle. It will take up or slack off a load chain up to a full 20½ in.—or more, if a longer chain is used in the binder. Accord-

ing to the manufacturers, this advantage over eccentric-type binders is especially important with springy loads where the binding chain or cable must be tightened by force through considerable distance in order to fully secure the load. Also, if a load settles in transit, the new coffing unit is easily tightened any amount without the necessity of releasing the entire load to take a new grab. Full strokes can be used for rapid take-up; half strokes permit minute adjustments. The Coffing Hoist-Binder weighs 10 lb and will exert a pull of 3000 lb. **Circle No. 4**

Mine Power Center

A new ventilated dry type mine power center is available from the *Westinghouse Electric Corp.* An integral, skid-mounted unit, the power center, features compact, low-height design—36 in. high, 45 in. wide, 104 in. long. The unit consists of a high-voltage section, a transformer, and a low-voltage section. The high-voltage section consists of a cable disconnecting plug and receptacle (optional) and a primary circuit breaker if desired. The low-voltage section may have as many as four L frame breakers, which are accessible through hinged doors on the side of the unit. Each breaker is equipped with ground-fault protection. The transformer is a horizontal type AVR triplex unit—three phase, 60 cycle, 80°C rise with dry-type class B insulation. Direct air cooling is used, with air entering the bottom louvers. **Circle No. 5**

Two-Speed Drill

A two-speed gear box of completely new design permits the operator of this new Desoutter drill to put through a small pilot hole first, then easily open out the hole with the larger drill. Effort normally required to drill ½ or ⅝-in. holes through steel is cut more than in half. Changing speed from high to low and back is quickly and easily accomplished by pressing and turning the change speed control button. The armature is hand former wound, with silk-taped coils, and runs on ball bearings of ample size. The gears are of heat treated chrome-nickel-molybdenum steel, mounted on ball or roller bearings. The body casing, as in all Desoutter portable electric tools, is pressure die-cast silicon-alloy providing strength without weight. Manufactured by *Newage International, Inc.* **Circle No. 6**

Milling Protector

One of the most practical machine tool improvements is now available in a new accordion-type way protector for milling machines. The *A & A Mfg. Co.* has designed this protector to prevent chips, dirt, and abrasives from scoring, scratching, grooving and cutting the ways. The protector will be mounted permanently and will fold automatically as the work bed is moved in either direction. On a way 20 ft long, the

protector will require approximately 24 in. mounting space on the end of the upper bed. Fabricated of Fairprene material designed by E. I. duPont for maximum performance for this application, it is impervious to oil, grease, dirt and abrasives. A dimensional sheet will be forwarded upon request. **Circle No. 7**

Free Literature

(8) DIESEL CRAWLER: A new TD-9 diesel crawler tractor catalog #CR-313-A has just been published by *International Harvester Co.* The catalog contains detailed specifications and information on how the TD-9 develops and applies its 40.5 drawbar hp. The improved TD-9 engine, with 51½ hp at the flywheel, features advances in fuel filtering and injection, oil filter elements good for 240 hours between drains, and better fuel economy from redesigned combustion chambers and a higher compression ratio. The forward mounting of the TD-9's rugged, swinging drawbar allows the tractor to pull drawbar loads with better leverage. The result is better balance and positive traction without the need of dead weight to hold down the tractor front end. Several varied job applications are illustrated with information on construction and operating features.

(9) PIPE INSULATION: *The Pittsburgh Corning Corp.* has announced the availability of a new booklet on Foamglas, an insulation for pipe and process equipment. This 24-page booklet discusses the advantages of Foamglas, listing its properties, typical data for cold, intermediate, and hot applications, details for insulating tanks, ducts, removable covers, accessory materials and prominent users. Its flexibility in on-the-job fabricating, durability, resistance to acids, light weight, and rigidity are the factors which make Foamglas unique in its excellence. Tables in the new booklet show sizes and shapes of Foamglas available in pipe insulation, standard blocks, beveled lags, and standard curved segments, and recommended shapes and thicknesses.

(10) EXCAVATORS: A new 32-p. bulletin on Marion all-purpose excavators has been announced by *Marion Power Shovel Co.* Bulletin #403 shows working views of the entire line of machines. The booklet lists condensed specifications and types of service to which the machines can be converted for use as shovel, dragline, pile driver, or coal loader and crane lifting capacities.

(11) EARTHMOVING EQUIPMENT: Booklet issued by *Euclid Road Machinery Co.* describes the model TD rear-dump engineered and built for heavy duty off-the-highway service. It has a payload capacity of 44,000 lb and 14.8 cu yd struck measure with standard body, 16.2 cu yd heaped. An air assist clutch permits faster, easier shifting of gears and reduces driver fatigue on jobs where grades and other conditions require frequent shifting. Hydraulic booster steering greatly reduces driver steering effort on difficult turns and rough roads of mining, construction and industrial haulage jobs.

(12) CONVEYOR BELT CLEANER: Spring type belt cleaner that can be adapted to fit nearly any belt conveyor is discussed in brochure available from *Stephens-Adamson Mfg. Co.* Self-aligning, spring steel wiper blades, set perpendicular to the belt surface, but diagonal to belt travel, wipe the belt clean and dry as it passes. Spring arms supporting the blades maintain a uniform pressure on the belt and allow blades to ride easily over obstructions such as belt splices. Wiper has an independent mounting assembly and can be easily adapted to fit existing conveyor installations. Adjustments and replacements can be made from either side without interrupting conveyor operation.

(13) CONVEYOR DRIVES: Built in three sizes, each of which has three distinct variations of kick, these drives are described in bulletin CC-506 available from *Goodman Mfg. Co.* The G-20 drive is effective in mines where clearances are ample and loads extremely heavy. It is equipped with a 20 hp motor and is capable of motivating large capacity, size 3 pan line. The G-15 drive is built for low seam operation or where space is otherwise restricted. This drive, powered by a 15 hp motor, accommodates size 1½ troughing. The G-12½ is used where conditions require frequent change in the location of the drive. It is powered with a 10 hp motor and is usually used with size 1 troughing.

(14) SEAMLESS TUBING: This 8-page booklet titled, "High Strength Seamless Tubing to Close Tolerances" is available from *Tube Reducing Corp.* It describes the method for producing precision, compression-formed tubing. How sizing is accomplished using various metals and bi-metal combinations is also discussed. Another section of the booklet deals with straight and tapered tubes having thin or heavy walls.

(15) PORTABLE CONVEYORS: A 12-page bulletin describing *Lake Shore Engineering Co.'s* complete line of flight and belt type portable conveyors and under car unloaders for handling coal, coke, gravel and other bulk materials has been released. Brief specification data are given on both electric and gasoline powered models and on hand-move and self-propelled conveyors. The flight conveyors come in 25, 30, 35 and 40 ft lengths, standard size. Gasoline or electric power can be used and they are available with all types of chutes and have antifriction bearings.

(16) CYANIDE PROCESS: In the process of cyanidation, gold and silver metallics are dissolved in solutions of potassium or sodium cyanide assisted by oxygen or air to cause chemical reaction. Primary crushers reduce ore to sizes suitable for further reduction by means of secondary crushers and grinding machinery. The ground product should reach a degree of fineness that will liberate all values to be dissolved, as cyanide solutions will not dissolve values encased in foreign material. This booklet is available from *Morse Bros. Machinery Co.*

(17) CHAIN DRIVES: A new bulletin on the installation, operation, and maintenance of chain drives and conveyors has just been published by *Chain Belt Co.* The illustrations show graphically the correct and incorrect ways of solving chain installation, operation and maintenance problems. Section 1 covers chain selection, underchaining, shaft and sprocket alignment and chain installation. Section 2 emphasizes the care of sprockets. Section 3 covers lubrication of various types of chain drives. Inspection and storage problems are covered in section 4 and the last section covers adjustment and repairs.

Mining Engineering **September**
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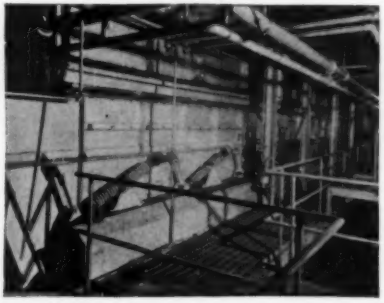

4½ by 70 ft Allis-Chalmers air-quenching grate cooler installed in processing plant where it cools large quantities of material from 2500° F to approximately 150° F.

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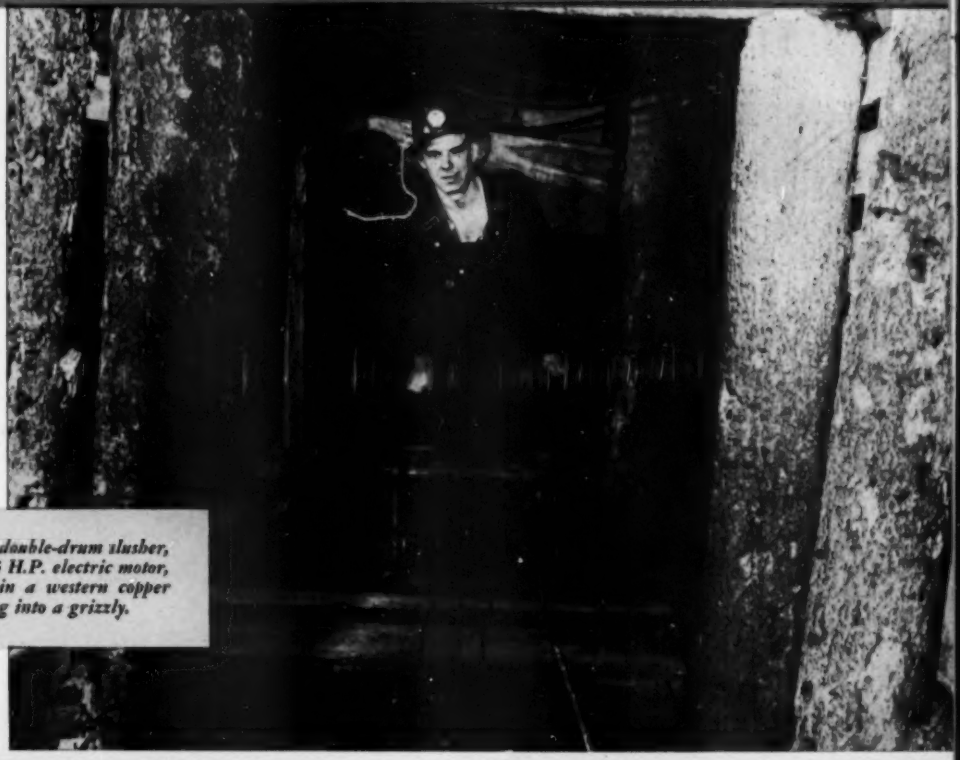


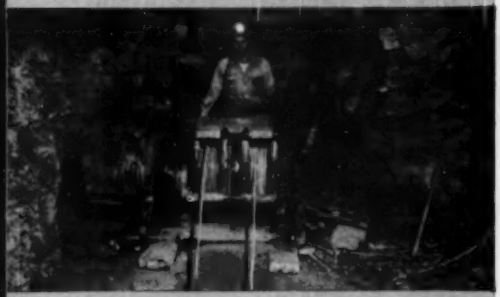
Joy AAF-211 double-drum slusher, powered by 15 H.P. electric motor, in operation in a western copper mine, scraping into a grizzly.

Joy E-111 Turbinair single-drum hoist on a timber setting operation in a large western mine.

Joy HL-3 Shovel Loader mucking out a drift round in a western copper mine.

Built with JOY'S intimate knowledge of mining problems... they're scraping millions of tons of muck every year

Turbinair driven 5 H.P. S-211 slusher scraping ore in a stope in a western fluorspar mine.



Electric driven CFA-211 double-drum slusher in operation in a Tennessee zinc mine.

25 H.P. B-312 electric slusher scraping ore in a large western Canadian mine.

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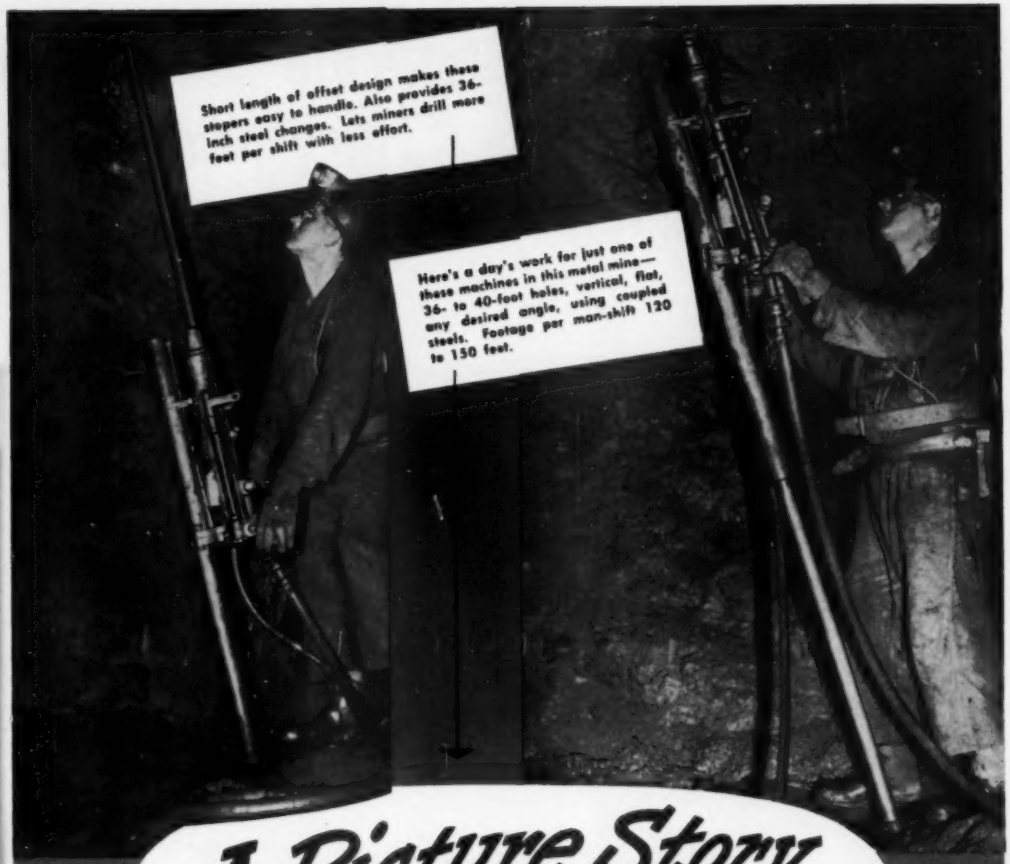
Short length of offset design makes these stopers easy to handle. Also provides 36-inch steel changes. Lets miners drill more feet per shift with less effort.
Here's a day's work for just one of these machines in this metal mine—36- to 40-foot holes, vertical, flat, any desired angle, using coupled steels. Footage per man-shift 120 to 150 feet.

A Picture Story of Lower Stoping Costs

. . . shows how Le Roi-CLEVELAND offset stopers drill extra footage, save you money

Take a good look at these pictures. Note the length of the drill steel. Fitted with carbide-tipped bits, it gives you 36" of drilling—3 feet with every change.

That's one of the reasons why Le Roi-CLEVELAND offset stopers are paying off in lower drilling costs.

But it's not the whole story. The machines shown here are equipped with downstroke rotation. This gives plenty of power and lets the miners drill holes from 36 to 40 feet in depth — using coupled steel. Total footage drilled per man-shift runs from 120 to 150 feet.

Performance like this does a lot to keep costs down. It also accounts for the growing popularity of Le Roi-CLEVELAND offset stopers wherever stoping is a problem.

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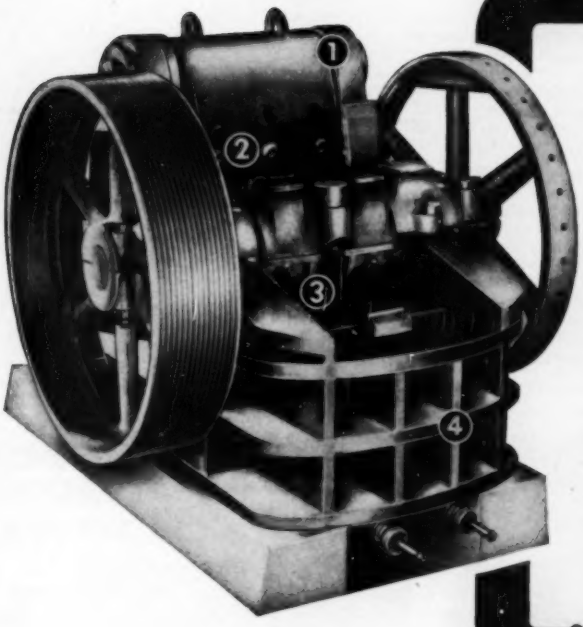

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Meet The Authors

E. A. LAURILA

A. M. GAUDIN

H. RUSH SPEDDEN

M. P. CORRIVEAU

Erkki A. Laurila *(Magnetic and Chemical Analyses of Ores and Mill Products Containing Magnetite and Ilmenite, P. 797)* is a physicist and a native of Finland, presently residing at Helsinki. He did his undergraduate work and also received his Ph.D. from the University of Helsinki in 1940. Besides teaching at the University, Mr. Laurila was general manager of the instrument dept. of the State Airplane Factory from 1943 to 1946. He is at present serving as professor of physics at the Finland Institute of Technology.

O. Jantti *(co-author with Messrs. Hukki and Laurila)* is a research chemist also a native of Helsinki, Finland. Following graduation from the University of Helsinki in 1937, Mr. Jantti was employed by a rubber manufacturer but since 1946 he has been with the Finnish Defense Forces. He likes to play the piano for relaxation.

R. T. Hukki *(co-author with Messrs. Jantti and Laurila)* is a Finlander but has received part of his education and training in the United States and Canada. After studying at the Finland Institute of Technology he went to Canada to Queen's University following this up with studies at Massachusetts Institute of Technology from which Institution he received his Sc.D. in 1944. After graduation he worked as a research engineer for Phelps Dodge at Morenci and then returned to Helsinki where he now heads the mineral dressing laboratory at the University. Mr. Hukki is an AIME member and previously contributed "Separations of Precious Metals from Anode Slimes by Flotation" to the *Transactions* as a co-author with A. M. Gaudin.

A. M. Gaudin *(Adsorption of Silver Ion by Sphalerite, P. 780)* is Richards professor of mineral engineering at MIT and needs no introduction to AIME members because of the many valuable papers he has contributed to AIME *Transactions*. Mr. Gaudin

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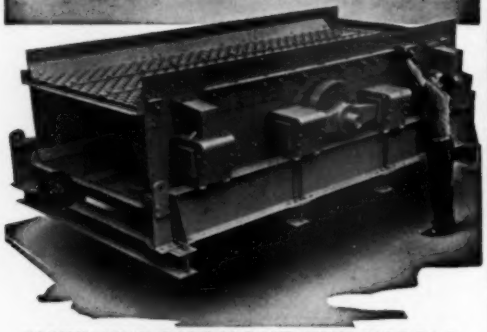

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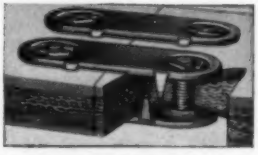

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Meet The Authors

was born in Turkey in 1900 and received his B.S. degree in 1917 from the University of Paris. After this he came to the United States to attend Columbia which university granted him his E.M. in 1921. Following graduation Professor Gaudin taught and did research work in mineral dressing at Columbia, University of Utah, Montana School of Mines and finally MIT. He is consultant for many well known mining firms. Among his works of writing are the books "Flotation" and "Principles of Mineral Dressing." Mr. Gaudin was married in 1926 and has three children.

H. Rush Spedden *(co-author with Messrs. Gaudin and Corriveau)* has presented four other TP's on mineral dressing before the Institute. An assistant professor of mineral dressing at MIT, he first went to that school in 1940, as a research assistant and instructor. Later he was sent to Bolivia as a production specialist for the U. S. Foreign Economic Administration, and the war years found him a lieutenant in the Corps of Engineers. Born in Colville, Wash., he attended high school in Spokane, and went to the University of Washington and the Montana School of Mines, acquiring an M.A. degree. Prof. Spedden lives in Worcester, Mass., where he turns to photography, canoeing, skiing, and camping for relaxation.

M. P. Corriveau *(co-author with Messrs. Gaudin and Spedden)* did his undergraduate work at the Michigan College of Mining and Technology receiving his degree in 1947. This phase of his education was interrupted for five years' service with the U. S. Navy Reserve. Mr. Corriveau is an experienced seaman as he had spent five years in the merchant marine prior to entering college in 1939. He received the SM degree from Massachusetts Institute of Technology in 1950 and is now associate research professor at Virginia Polytechnic Institute. Mr. Corriveau says that he would like to have a hobby but between his interest in mineral dressing and his family of two boys and two girls he is fully occupied.

A. W. Asman *(Characteristics of Mechanized Mining Sections, P. 803)* was born in Lombard, Ill., and attended the University of Illinois receiving his mining engineering degree in 1938. Before going to Pennsylvania State where he is now chief division of mining, he spent 3 years with ARMCO Steel Corp. During the war he was with the combat engineers for 4 years. Besides AIME membership, Mr. Asman is a member of Coal Mining Institute of America, a registered professional engineer, and a reserve Army officer. Professionally he is interested in mine mechanization and strata control but for hobbies golf and photography claim his interest.

H. B. Gundersen *(Employee Training Reduces Costs, Increases Labor Efficiency at Utah Copper, P. 768)* had a long history of industrial training experience before he joined the Utah Copper Div. of Kennecott as supervisor of training. He graduated in 1926 from Utah State Agricultural College and in 1931 he received his M.S. from University of Wisconsin. He has worked in varying capacities in the field of industrial training for the Branch Agricultural College, Cedar City, Utah; U. S. Government Apprentice Training Service, Washington, D. C.; Pennsylvania State Dept. of Education, Harrisburg. Before joining Kennecott AIME Member Gundersen returned to Utah, his home state and favorite fishing and photography grounds, as president, Salt Lake Vocational School.

Charles M. Haas *(Wire Rope—How It's Made, How to Take Care of It, P. 772)* is an engineer who has been intimately connected with the subject on which he writes for his entire working career. He received his education in engineering at the Universities of Cincinnati and Ohio State before going to work as a trainee of Bethlehem Steel Co. As assistant chief engineer of the Williamsport plant he has ample opportunity to indulge his chief interest—wire rope as used on the iron range. Mr. Haas, a junior member of Masonic bodies including Shrine, is a registered professional engineer in Ohio and Pennsylvania and a member of ASME.

James R. Stuart *(Developing Mesabi Orebodies Under Lake Beds, P. 777)* born and raised close to the Lake Superior iron country at Madison, Wis., has naturally pursued a career as a mining engineer on the Range. He studied civil engineering and geology at the Universities of Wisconsin and Minnesota. He was employed for over 10 years around Hibbing and Biwabik by Pickands Mather & Co., finally as assistant superintendent of the Embarrass mine. He is at present chief engineer of the Meriden Iron Co., Hibbing, Minn. Mr. Stuart is an AIME Member.

John S. Brown *(A Graphic Statistical History of the Joplin or Tri-State Lead-Zinc District, P. 785)* received his Ph.D. from Columbia University in 1925 having previously attended Missouri School of Mines and also George Washington University. He was with the U. S. Geological Survey from 1917 to 1925 and then went with St. Joseph Lead Co. with which organization he is still associated. Mr. Brown is an AIME Member as well as a member of Geological Society of America, Society of Economic Geologists, and the Mineralogical Society of America.

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Trends

Jess Larson has become head of newly-formed Defense Materials Procurement Agency.

James Boyd, no longer head of DMA, will be able to concentrate on Bureau of Mines.

W. C. Schroeder is acting head of DMA and also an assistant director of the Bureau.

NOTHING makes the run-of-the-hall Congressman feel quite so secure as to be on an investigating committee. It's sure fire publicity for one thing and is a convenient excuse for absence from Congressional sessions when controversial issues are being balloted. The minerals procurement program has just had a thorough investigation by Congressmen of the House Interior and Insular Affairs Committee who heard valuable testimony from men like John D. Morgan, director of materials procurement, DPA. He listed over 40 government agencies concerned with mineral affairs. Testimony disclosed the justification for many of the agencies but Congressmen and mine operators have been regarding the defense minerals program in the same light as did the mining student who remarked to the descriptive geometry prof "it's not the intrinsic difficulty of the problem which gives me trouble; it's the multiplicity of detail."

Unlike other investigations, this one caused the White House to take action. On August 1, Mr. Truman issued a statement: "The Federal Government's programs for purchasing and increasing the supply of critical and strategic materials are vital to the security of the Nation . . . . Accordingly, I am creating, under the authority of the newly extended Defense Production Act, a new independent agency whose sole job will be to procure and to increase the supply of critical and strategic materials at home and abroad . . . ." All critical and strategic materials procurement functions have been transferred from the Defense Minerals Administration, General Service Administration, and the Economic Cooperation Administration and are now centered in a newly formed agency, the Defense Materials Procurement Agency which will report directly to the Director of Defense Mobilization. Mr. Truman stated that he intended to appoint Jess Larson, at present Administrator of General Services, to head the new agency.

From DMA in the Department of the Interior the following authority was transferred to DMPA: responsibility for materials supply expansion including programs for same; responsibility for recommending tax amortization for materials expansion action; responsibility for certifying Defense Production Admin. loans to the RFC for materials expansion actions. From the General Services Administration the responsibility for materials procurement under the Defense Production Act was transferred. ECA will now delegate to DMPA responsibility for serving as the agency to perform ECA's materials procurement actions.

The new agency gathers much of the authority under one roof which had previously been scattered over many agencies. Presumably minerals contract requests for accelerated amortization, loans, etc. will be expedited but this will depend on Jess Larson's administrative methods.

The Department of Interior will continue to administer the domestic exploration loans program authorized by the Defense Production Act and will carry on the priorities and allocations functions with respect to metals and minerals under the act.

Close on the heels of this announcement it was learned that James Boyd, who had been directing the Defense Minerals Administration, since its inception, had been relieved by Interior Secretary Chapman and replaced by W. C. Schroeder as acting director of DMA. Mr. Schroeder was head of the Bureau of Mines synthetic liquid fuels program. In addition to becoming acting director of DMA, Schroeder has also been appointed to a newly created assistant directorship of the U. S. Bureau of Mines. At the Bureau of Mines in his capacity as director, James Boyd is over Schroeder.

Approximately 50 pct of the Bureau's budget is spent on synthetic fuels and the program is steadily increas-

ing in importance. Interior is requesting that $455 million in Federal funds be authorized by Defense Production Administration to cover a 12-year guarantee of 1951 prices to a proposed large scale plant for manufacture of synthetic liquid fuels and chemicals. (If present price structure obtains for the 12-year period no public money will have been spent.) All reports from the director of synthetic liquid fuels are handed up to Interior Secretary Chapman through the office of the director of the Bureau of Mines and presumably have his approval. The appointment of Schroeder to assistant director of the Bureau brings the synthetic liquid fuels program closer to the Director's office in line with its importance.

THE Korean emergency has hastened the arrival of the new "wonder metal" titanium. By all indications the present producing capacity of the titanium metal industry will be increased from 500 tons per year to 10,000 tons by the end of 1952. This is an 800 pct expansion of the industry and is a mighty first step for the new metal.

Ilmenite, rutile, and arizonite have long been the main sources of titanium which has been consumed in industry in the oxide form (TiO_2) in the amount of ½ million tons annually, primarily for white pigment in paint, linoleum, textile, rubber, printing, and ink manufacturing. Even this figure of oxide production will someday be exceeded by metal output because its physical properties of lightness combined with strength and resistance to corrosion are very useful in the transportation field. The only drawback at the present time is price which is $5 per lb for sponge, $7 for ingot, and $15 for sheets in quantity.

Titanium ores are treated with acid to make titanium dioxide. This product, and sometimes the ore directly, is treated with chlorine and carbon to make titanium tetrachloride. The Kroll process starts with the tetrachloride which is reduced by magnesium in a reactor. The magnesium replaces the titanium in the salt, leaving metallic titanium. A difficulty of the process is that the metal produced is in a sponge which must be separated from the remainder of the mass. This is accomplished by distilling off the magnesium chloride at low pressures. The metal must be melted and cast into ingots in a vacuum furnace or in an inert atmosphere. The treatment of titanium ores to make metal is expensive. Without including the cost of plants to produce the starting compound and the magnesium used, the Kroll process requires a plant investment of $1500 a ton annual capacity. Since titanium has become important in the jet aircraft and guided missile programs—an estimated 18,000 tons are needed annually—the Government has taken a great interest in it. About $10 million are being spent annually on research to develop a cheaper process for making the metal. Electrolytic methods are receiving a great deal of study.

A rash of new companies has appeared in the titanium business. Foremost is the Titanium Metals Corp. which is a combine of National Lead and Allegheny Ludlum. National Lead has the orebodies and does the extractive metallurgy turning over sponge to Allegheny Ludlum for making titanium metal into structural shapes and forms. Titanium Metals has recently acquired the $150 million plant formerly owned by Basic Magnesium, Inc. at Henderson, Nev., an installation built during the past war by the Government. Leases have been obtained for required sections of Basic Magnesium and an additional $15 million will be spent in equipping the property for titanium production. Hoover and Davis dams will supply power to the plant, chlorinators already in the plant will be used, and the magnesium cells will be used to produce magnesium chloride. The plant actually started production in July, but capacity operation of 3600 tons of titanium metal a year is not anticipated until late 1952.

The only other producer of titanium sponge is duPont which has been supplying the other companies who are making and experimenting with the metal. DuPont's biggest customer of sponge and the only other producer of titanium metal in structural shapes and forms is Rem-Cru. This company is a combination formed by Remington Arms (in which duPont has large stock holdings) and Crucible Steel. Other customers are the recently formed combination of P. R. Mallory and Sharon Steel; and Horizons Titanium Corp. which company is reportedly working on a process for the recovery of the metal that according to laboratory test work will reduce the cost to a dollar a pound. DuPont is expected to expand production shortly and is said to be negotiating with the government for the construction of a plant with capacity of the same order as the Titanium Metals' Henderson plant. Kennecott and New Jersey Zinc are exploiting the Allard Lake, Que., iron-titanium orebodies through the Quebec Iron & Titanium Co. This company markets the oxide and is not in the titanium metal producing business yet. The Crane Co. is making titanium metal from titanium tetrachloride and using it for experimental purposes in the manufacture of valves. This company is also examining ore deposits with the object of acquisition for their own source of titanium.

The baby industry is due for rapid growth with the vitamins being fed by Uncle Sam. Government will provide certificates of necessity, allowing the fast 5-year tax write offs for a major part of the cost on titanium plants erected by private industry.

AT the annual meeting of the American Society for Engineering Education held in East Lansing, Mich., on June 26, Professor W. B. Plank, head, dept. of mining and metallurgy, Lafayette College, evaluated the acceptance of the 5-year engineering curricula. He said the objectives and motives for adopting the longer curricula are mixed but the reason most frequently put forward for adopting it is the desire to broaden and enrich the engineer's undergraduate education with cultural subjects.

Besides the lengthened curricula at some of the engineering schools there has developed in recent years a cooperative arrangement between liberal arts colleges and engineering schools, called the "three-two plan." This is an arrangement whereby students spend three years at the liberal arts college and then two years in engineering school for which they are granted the A.B. and Bachelor of engineering degrees.

Professor Plank draws the conclusion that the scarcity of engineers and the smaller enrollments resulting from the change in population ages will make the 5-year curricula less acceptable in the immediate future. Also examination of the longer curricula being given indicates that although the humanistic social subjects are broadened, much more time is devoted to technological subjects than in most 4-year programs.

Several authorities of ASEE were quoted to the effect that 4 years would be long enough for a great majority of engineering students. It would be better to stress post graduate work for the few who will eventually go into research, for example. Professor Plank closes by suggesting the alternative to the 5-year curricula of a cooperative program with industry whereby the 4-year graduate enters an approved industrial training course at the successful conclusions of which, with proper regulations, the engineering school confers the professional engineering degree.

● The widespread use of triple-alloy steels containing Nickel, chromium and molybdenum is based on extensive experience in widely divergent engineering fields.

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All critical and strategic materials procurement functions have been transferred from the Defense Minerals Administration, General Service Administration, and the Economic Cooperation Administration and are now centered in a newly formed agency, the Defense Materials Procurement Agency. DMPA will report directly to the Director of Defense Mobilization. Mr. Truman stated that he intended to appoint Jess Larson, administrator of General Services to head the new agency (see Trends P. 756).

W. C. Schroeder has been named acting director of the Defense Minerals Administration replacing James Boyd. He has been named also to a newly created assistant director position of the Bureau of Mines serving under Mr. Boyd who is director. Schroeder was formerly head of the Synthetic Liquid Fuels Division of the Bureau of Mines.

Domestic refiners of copper from ore or concentrates and other copper-bearing materials of foreign origin were permitted to increase their quotation for the metal to 27½¢ per lb by OPS Supplementary Regulation 46 issued on July 25.

AEC exploration on the front range of the Colorado Plateau over the past three years has resulted in the selection of 5 sites for intensive examination. They are the Leyden coal bed; the East Calhoun; Wood, and Kirk mines of the Quartz Hill area near Central City; the Copper King mine north of Fort Collins; the Jo Reynolds mine of the Larson district near Idaho Springs; and the Harpuda ranch, south of Canyon City. $200,000 will be spent on the 5 sites.

Control of basic metals - steel, copper, and aluminum - by CMP will be extended to all industry beginning Oct. 1. DPA Administrator Manly Fleischmann said the broadened order would end the scramble for reduced supplies.

CMP is causing unnecessary chaos in the steel market according to E. C. Grace, chairman of Bethlehem Steel. He urged that CMP be restricted to direct military requirements for steel which are only 10 pct of production. On the basis of a month-long survey made by his company he said that "consumers will be overstocked by the end of the year resulting in loss of control of steel's destination."

An $8 million iron ore unloading pier is to be constructed on the Delaware river at Philadelphia by The Pennsylvania Railroad. The new pier, with rated ore handling capacity of 2400 tons per hr, will be begun this year and is scheduled for completion by summer 1953.

A request has gone forward from the Secretary of Interior to DPA asking that $455 million in Federal funds be provided to cover a 12-year guarantee of 1951 prices for a proposed large-scale plant for manufacture of synthetic liquid fuels and chemicals from coal.

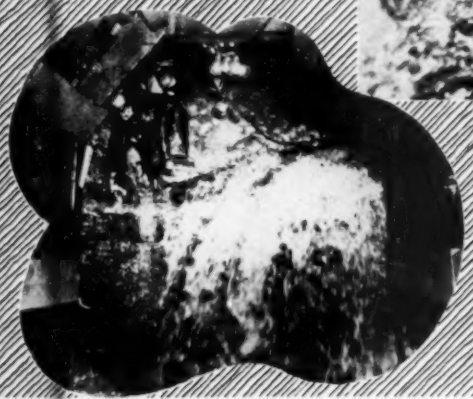
Increased requirements for the military program and expansion of defense supporting industries caused the demand for platinum in 1950 to reverse the downward trend that had persisted for several years. Domestic sales were 102 pct greater than in 1949.

CASE HISTORY OF A SUCCESSFUL TUNNEL JOB

FROM THE EIMCO FILE T101

LEADVILLE DRAINAGE TUNNEL

Proposed tunnel length, 17,300; Length completed at end of war, 6,600; Tunnel size, 9' x 10'6"; Supported section, 64% of length; Rock section, 36% of length.



MODEL 12-B

MODEL 40-M

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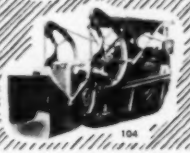
MODEL 21

MODEL 15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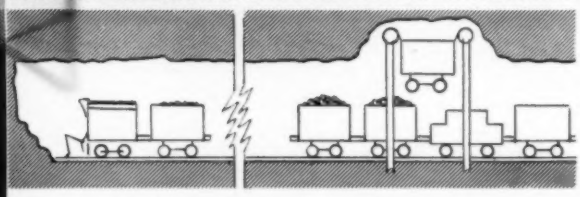

"Cherry Picker" method of car switching was used in the Leadville Tunnel. The frame was erected to lift the empty above the train of loads moving out, then lowered to be moved to the face for loading.

Equipment used for rock loading on contract jobs must be well built, proved, heavy-duty equipment—capable of standing up to the most difficult—most unexpected operating conditions.

Tunnels are carefully surveyed before they are started. Test holes are drilled from the surface at selected spots along the tunnel line to determine the ground structure through which the tunnel is to be driven, but even then, as in the Leadville Drainage Tunnel, there are unseen glacial channels and faults which make progress slow and dangerous.

Loading in the Leadville Tunnel was done with Eimco Model 21 RockerShovels. These machines were subjected to the most severe operating conditions working in water at 37° temperature with an average flow of 3000 to 7000 gallons per minute.

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MINING
ENGINEERING

EDITORIAL

COFFEE AND THE BOSS

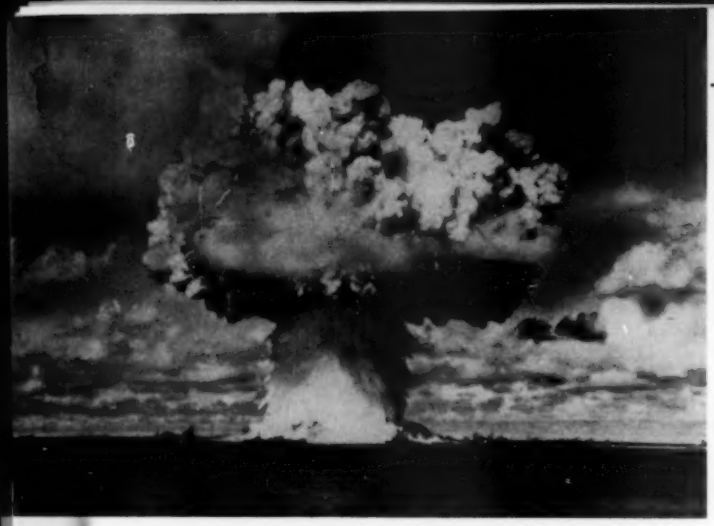
A FEW nights ago while working in the small hours of the morning on a clarion message intended for this page, we repaired to the kitchen for coffee, as is our wont when the solitude of the late hour and the stillness of the night seduce thoughts from the job at hand to reminiscences. The thought occurred, as we slowly dissolved the instant coffee in boiling water, that this modern world of canned, frozen, and dried foods deprives us of some of the subtler and therefore more delightful pleasures of life. We recall the aroma of boiling coffee which greeted us on getting up in the morning before the ease of instant coffee deprived us of the aroma from the old coffees. This line of thinking led us to place the blame on our wife for taking the easy way of making coffee and thereby depriving us of some of our enjoyment. From thinking about our spouse, it is only a short step to thinking about "the boss" or bosses in general.

You know, for a long time bosses have been taking the easy way out with regard to personnel relations effecting their engineers. Prior to the present bull market for engineers, the profession was suffering from comparatively low salaries in relation to the cost of living. Engineers, whether in production or the engineering department, often found that labor had a fatter pay envelope. This situation led to a great deal of dissatisfaction culminating in talk of engineer-unions and, in some industries, the actual formation of these unions. The situation was bad. The professional pride of the engineer was at a low ebb because he was considering sacrificing the most precious of his prerogatives—his freedom of initiative. He was also mad at the boss for taking the easy way; not facing the problem.

Since Korea, a tremendous industrial boom has placed a premium on engineers. Today they are receiving the highest salaries in history, not only in total amount but also with respect to other professions and organized labor. This fortuitous circumstance has saved the profession a great deal of grief. However, no one can derive any satisfaction of accomplishment from the situation for it has been only partially resolved and this by happenstance.

We don't anticipate too much difficulty getting our wife back to serving pot coffee even though it means washing the pot. It shouldn't be much more difficult to persuade the bosses to substitute a *planned program* of salary adjustment rather than the laissez-faire tactics in current use which leave both parties exposed to the vicissitudes of the market. The program should begin right now because most of the adjustment that has taken place is in the starting salary group; many of the old hands deserve increases too. A program of this type will not be contributory to inflation as it is merely an adjustment to the price index, a reflection of the 55¢ dollar. Furthermore, it is needed if the supply of engineering skill to keep the defense effort rolling is to materialize. Those who direct the mining industry need have no misgivings because the cost of engineering is relatively small in comparison to other costs. The Salary Stabilization Board does not object to planned salary adjustments.

The fact is that, geologically speaking, we aren't on this earth very long and what's more satisfying than the aroma of freshly boiled coffee, a wife's satisfaction in a pleased husband, an engineer's respect and friendship for his boss, and the boss's satisfaction in having licked the toughest of all problems—one in human relations—to the benefit of all concerned.



URANIUM

THE atom has put man on the spot. He has to make up his mind—one world or none. Atomic warfare provides the unpleasant possibility of wiping out civilization. In its infancy, the Atomic Bomb killed or injured 200,000 of the 343,000 population at Hiroshima. Experts estimate that from 25 to 60 million people would be killed in the first 24 hr of an atomic attack launched against the United States.

Ironically, peaceful application of atomic energy would undoubtedly bring about a Golden Age for mankind, with farm and industrial production at new highs to provide for the wants of all, and disease virtually nonexistent. If this sounds like dreaming, consider the progress made in a few fields of science today.

Cancer, the dread killer, is succumbing to medical science. Scientists have discovered that cancerous growth is more vulnerable to radio activity than normal tissue. By careful treatment, radioactive substances can be used to destroy cancerous growth with a minimum of harm to surrounding tissue. While radium was first used several years ago in this treatment, scarcity of that element made it unavailable to all but a few sufferers. Science has discovered more abundant substitutes.

Isotopes are the key to much of this work. An isotope is an element in which all the atoms are of uniform weight. Most elements are composed of a mixture of atoms similar in chemical properties but different in weight; like chlorine in which two kinds of chlorine atoms have rough atomic weights of 35 and 37.

The radioactive property of the isotope permits the scientist to follow its progress in the body by means of a Geiger counter. For example, when a little radioactive iodine is administered to the body along with normal iodine, the progress of the entire drug can be traced by means of the Geiger counter. This technique has already added volumes to the knowledge of structure and processes in normal and abnormal thyroid glands.

Isotopes have been used successfully in the direct treatment of some diseases. Take radioactive phosphorus, P_{32}. It successfully combats leukemia, a disease in which the number of white corpuscles becomes abnormally high. P_{32} concentrates in the bone marrow where the cells are formed and inhibits reproduction.

Medical research is not the only beneficiary of isotope production. Industry benefits by using these tracers in a variety of ways. Some oil companies have successfully used them in exploration. Metallurgists are using them to study metals and alloys. Some metals, for example, should theoretically be ten times as strong as they are. Radioisotopes may help the scientist discover why not.

Nuclear fission is a source of intense heat and tremendous energy is present in a relatively small mass. Both of these factors make it ideal as a fuel. But important obstacles are (1) the tremendous amount of shielding necessary to protect personnel, and (2) the critical mass (the amount of fissionable material that must be present to bring about nuclear fission) is a considerable quantity. Space savings would be negligible in power plants until they got to the size of 10,000 to 50,000 kw. In that size plant space is not a critical consideration and dollar savings, based on present costs, would not be favorable. Ships, where space for fuel is an important consideration, probably represent the most fertile field for the atomic energy power plant. Work on this has been in the experimental stage for some time.

The over-all effect of atomic energy developments in this direction would mean the arrival of the benefits of a highly productive civilization to all corners of the globe. Lack of fuel would no longer be an obstacle to building a factory in any part of the world, since a small mass of fissionable material would supply enough energy.

These and a multitude of similar accomplishments are within the grasp of mankind. The time draws near when the choice will be made between a dev-

Procurement of uranium is vital to the future of the Nation. Its utilization for atomic energy can destroy mankind or raise an unsurpassable civilization—the problem of the statesmen. Uranium poses a challenge to the mining profession. Evanescent in occurrence, its discovery and mining can mean substantial profits, plus safeguarding the future of the Nation.

Swords or Plowshares

astating war and a peace of abundance. Whether the choice is for peace or war, however, the entire development of atomic energy depends on one mineral—uranium.

Uranium forms more than 100 minerals—more than 200, if all the minerals in which it is a minor constituent of the lattice are counted. Like the alkali, the rare earths, aluminum, vanadium and phosphorus, uranium shows a strong affinity for oxygen. It has 3 valences and may be either a cation or an anion. It is active chemically and combines with many elements to form compounds, most of which are soluble in acid solutions.

It is this chemical overactivity that makes uranium so troublesome. It provides the geologist with more exceptions than rules. The numerous compounds and the ready solubility of each, makes uranium deposition a wil-o-the-wisp affair. Favorable structures are carefully tracked down, only to find that uranium minerals have been leached out. The numerous geologic environments in which concentrations of uranium minerals are found and the range of ores that have been developed not only complicate the geology, but provide serious problems for the ore dresser.

The most important uranium minerals are oxides, like uraninite or its colloform equivalent, pitchblende; phosphates, like autunite and torbernite; and vanadates, such as carnotite and tyuyamunite. Of lesser importance are the carbonates, silicates, sulphates, and columbates. Uranium is also found in a variety of materials such as phosphate, monazite, zircon, and carbonaceous matter where it proxies for another element of similar ionic radius or is attached by valence ions on the lattice surface. Some hydrocarbons contain uranium too.

Mode of Occurrence

Deposits are known to occur in igneous, sedimentary, and metamorphic rocks and the grades in between. Uranium deposits in igneous and metamorphic rocks occur mainly in hydrothermal veins. Of less commercial importance are disseminated orebodies and the scattered amounts that are found in pegmatites throughout the world.

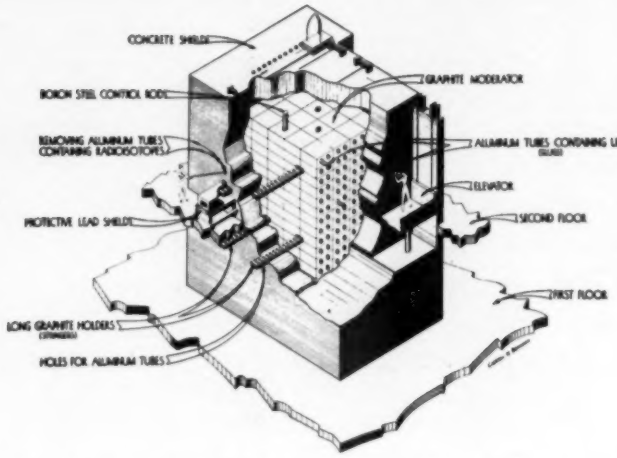
Major hydrothermal uranium-bearing vein deposits are typically mesothermal in character with pitchblende as the important uranium mineral. Most likely host rocks appear to be felsic intrusives and sandy metasediments. Associated minerals include iron, copper, cobalt, lead, silver, nickel, and bismuth.

Solubility of pitchblende in slightly acidic waters has led to the secondary redistribution of uranium in the oxidized parts of vein deposits near the surface, especially in dryer climates. In these oxidized deposits, uranium minerals are mostly phosphates, sulphates, and hydrous silicates. The grade is usually lower than the unoxidized vein. General characteristics of oxidized deposits are persistent tensional fractures filled by secondary metallic minerals and gangue minerals that are typical of hydrothermal deposits; minerals that include base metals in the lattices, and wall rock that has been altered in part to clays with high base-exchange properties and kaolinite.

Primary deposits assaying 0.2 pct or more U_3O_8 are currently being mined at a profit. Limited tonnages necessitate grades of this order. Oxidized vein outcrops may contain 0.1 pct U_3O_8 or less.

Several volcanic flow rocks of the Southwestern United States contain low grade concentrations of uranium. Some of these deposits are distributed through broad shear zones covering large areas, while others appear to be structurally controlled by local flexures and complimentary fractures. Uranium minerals commonly found in these disseminated deposits are autunite, shroeckingerite, and uranophane. To date, none of these deposits has produced ore.

Pegmatites are sources of high grade specimens but not much else. None have yet been found capable of producing large tonnages. A few pegmatites have



The nuclear reactor, or uranium "pile," produces a product which may be used for peace or war.

yielded uranium minerals as a by-product of mica or feldspar mining.

Deposits in Sedimentary Rocks

Uranium deposits in sandstone, siltstone, shale, and limestone are unique to the type of rock in which they occur. Since most of the knowledge compiled on these types of deposit is based on geologic studies in the United States, details are covered under United States deposits.

Geo-politically, distribution of uranium minerals, judging by discoveries to date, is haphazard, with both sides of the iron curtain having access to important deposits, and both sides determinedly looking for more. Here is how the world picture shapes up.

USSR

Russian research in radioactive minerals has been going on since 1900. Field work until 1914 was concentrated on the most promising deposits in the Fergana Valley (Central Asia), Siberia, the Caucasus, Transcaucasus, and the Urals. By the time the Soviet regime took over in 1918, only the Fergana Valley deposit was worth following under the economic conditions at that time.

Efforts at Fergana were concentrated on the Tyuya Muyun deposit where more than 2 million lb of ore reported to assay 0.97 pct U_3O_8 has been mined. The ore had also contained vanadium and copper. The veins at Tyuya Muyun are in metamorphosed limestone. By 1933 some 35 veins had been discovered, five of which, near the center of the deposit, contained uranium, vanadium, and copper. Widths vary from a few inches to 4½ ft with run-of-mine ore averaging 1.5 pct U_3O_8. Irregularity of the deposit makes ore reserve estimates impossible, but the mine is probably contributing substantially to the USSR's supply of uranium today.

Most important source that the Soviets have are the pitchblende veins of the Jachymov region of Czechoslovakia. Reports of refugees slipping through the iron curtain indicate that the deposits are being worked frantically with upwards of 3000 people being pressed into labor to bring out the ore. The magnitude of the effort expended in this area seems to imply that it is the principle source of ore for the USSR.

All pitchblende from the Erzgebirge region of eastern Germany is also flowing into the Russian atomic plants. Other regions, like those in Central Asia, while not of comparable significance, cannot be discounted as sources of uranium.

Africa

World's largest producer of high grade uranium ore is the Shinkolobwe mine of the Union Miniere du Haut Katanga. Its ore constitutes one of the main sources of supply of uranium metal used by the United States.

Veins varying in width from a few inches to several feet, pinch and swell vertically and horizontally. They may contain pitchblende with little other filling, or may consist of cobalt or copper sulphides with or without associated pitchblende. Elsewhere, pitchblende associated with cobalt minerals, occurs in a quartz-carbonate matrix.

In addition to the principal uranium and cobalt minerals, Shinkolobwe ores carry significant quantities of copper, molybdenum, and iron sulphides, and gold, platinum, and palladium.

Oxidation of the orebodies has extended several hundred feet down. in the near-surface deposits, there are many complex hydrous oxides, phosphates, and silicates, including torbernite which accounts for more than half of the uranium found in the oxidized zones of the orebody.

Ore of extremely low uranium content has been found in tailing piles on the Rand in tonnages so great that treatment on a large scale will prove economical. Plans have been completed for a plant to extract uranium and some minor values. Shipments are expected to begin in 1952.

Australia

Uranium ores of probable commercial importance occur in South Australia at Mount Painter, 300 miles north of Adelaide, and at Radium Hill, 70 miles west of Broken Hill. According to *Mining Magazine*, the South Australian government has been carrying on geologic studies through diamond drilling and underground work since June 1946, at Mount Painter. Although chief minerals mined to date have been autunite and torbernite from the near-surface oxidized zone, the deposit is reported to consist mainly of primary uranium minerals disseminated in granite and pegmatite. Ore minerals at Radium

Hill, where work has been in progress for two years, are carnotite and davidite.

Canada

Canada is the third largest producer of uranium ore in the free world. At present, all of this ore is produced by the mine of the Crown Company, Eldorado Mining and Refining (1944) Ltd., in the Northwest Territories.

Development at numerous properties in the Goldfields area on the shore of Lake Athabasca in Saskatchewan, and several properties in British Columbia is by private companies. Some exceptionally rich pitchblende finds have been made in the area about 50 miles north of Sault Ste. Marie which may prove to be producers. Meanwhile both Crown and private companies report a steady increase in reserves. A custom mill is planned to treat ore from the Lake Athabasca region.

On the business end of Canadian atomic energy, the government reports the Chalk River project going at full swing with a steady flow of isotopes being produced.

United States

The bulk of uranium ore production in the United States has come from the Colorado Plateau area, although some uranium is being produced from vein deposits such as those that occur at Marysvale, Utah, and active exploration is underway in the entire western Cordilleran and the limited Canadian shield areas.

The Colorado Plateau is a physiographic province covering about 130,000 sq miles of eastern Utah, western Colorado, northwestern New Mexico, and northeastern Arizona. This area is almost completely covered by flat lying sediments. Over most of the uranium-bearing portion of the plateau, erosion has carved out a youthful topography of mesas and canyons. Uranium mineralization has been found as low in the stratigraphic column as the Permian Coconino sandstone and upward through the Morrison sandstone of the Jurassic, but the most important deposits have been in the Triassic red beds in the Shinarump, Moenkopi, and Chinle, the Todilto limestone, and the Entrada and Morrison of Jurassic age. Several distinctive types of deposits have been found.

Carnotite deposits occur in most of the formations on the plateau, but the important producing horizons are the Morrison and Entrada formations (Jurassic) and the Shinarump (Triassic). Most of the ore deposits are roughly tabular in shape with the greater dimensions in planes parallel to the horizontal bedding of the enclosing sandstone or mudstone. Orebodies often tend to cut across the stratification however, and in places they thicken to form concretion-like masses known as "rolls". Fossilized tree trunks, branches and leaves are common, and some of the richest ores consist of logs partly replaced by uranium and vanadium minerals.

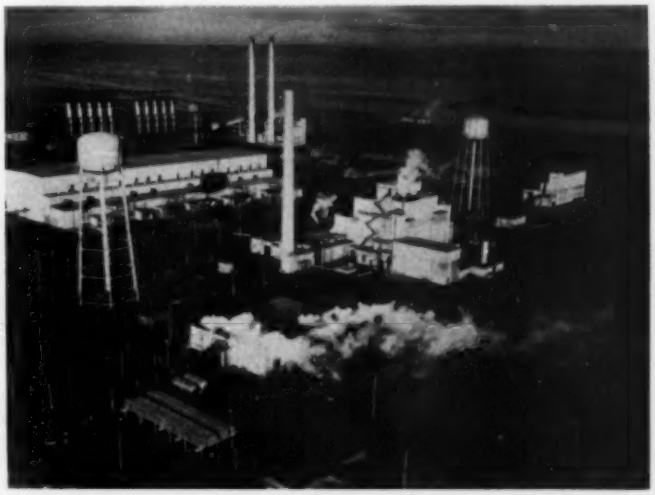
These features are generally associated with ancient stream channels, which seem to represent the dominant structural control of the orebodies. Whether the minerals were precipitated from ground water solutions after sediments had accumulated but before deformation and fracturing, or whether the major uranium-bearing solutions formed the deposits in post-Cretaceous time, is a subject of debate.

Ore-forming minerals, mainly carnotite, vanoxite and hewattite, are deposited as coatings on grains of sandstone or along the parting planes of shale. The ore commonly contains 0.2 to 0.4 pct U_3O_8 and 1.5 to 2 pct V_2O_5.

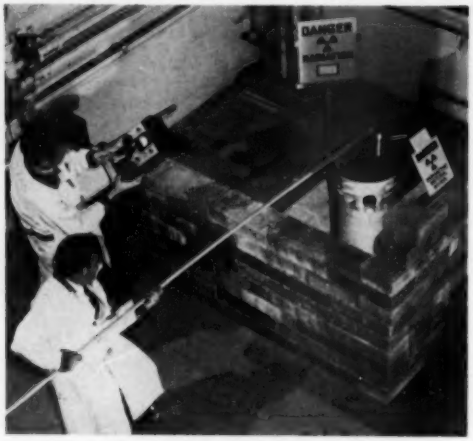
Copper-uranium deposits occur at many localities in conglomerate, sandstone, and shale formations in the western and southern parts of the Colorado Plateau. Mineralization of this type appears to be restricted to the base of the Shinarump and the upper few feet of Moenkopi immediately beneath it.

Host sandstones of the copper-uranium deposits are typically lenticular in character, thinning and thickening markedly along the strike of the bedding. Geologists interpret this as indicating fluviatile deposition in and near stream channels. Mineral concentrations appear to be in or near the thickest and lowest parts of the beds, along the ancient channelways. Deposits are spotty and erratic in distribution. Although the uranium and copper minerals generally occur together, the easily identifiable copper minerals are not a reliable guide to ore.

Because of mineralogical differences between the oxidized and unoxidized portions of the orebody, im-



The Richland, Wash., plant, shown here, is one of three main plutonium production areas.



Studying applications of radiation to industrial processes, these technicians at Brookhaven National Laboratory exemplify by their precautions the many problems of shielding before atomic energy can be used for industrial power.

provement in grade can be expected as development advances from the exposed rim. Primary minerals include pitchblende, pyrite, chalcopyrite, covellite, bornite, galena and gersdorffite are typically altered near the surface to hydrous sulphates, silicates, carbonates and arsenates.

Copper-uranium deposits that appear to contain several thousand tons, are considered potential ore producers if the oxidized rim outcrops assay more than .05 pct U_3O_8.

Uranium-bearing asphalt or asphaltite occurs in lenses, globules and irregular masses in certain sandstone beds of Triassic age in southern Utah. In the Temple Mountain deposits of the San Rafael Swell, uranium and vanadium-bearing asphalt, associated with pyrite, cements the grains of sandstone and forms replacement masses. In other parts of the Swell, uranium is present in "pure" asphalt with small amounts of copper. Gypsum is almost universally associated with these deposits.

Uranium bearing limestone deposits of commercial importance occur along the northeast flank of the Zuni uplift in northeastern New Mexico. Ore is found in the upper 2 or 3 ft of the Todilto formation with mineralization extending downward into lower beds along joints and bedding planes. Uranophane, carnotite, and tyuyamunite are the most abundant uranium minerals. Considerable ore tonnage is expected from these deposits which average about 0.2 pct U_3O_8 and 0.15 pct V_2O_5.

Outside of the Colorado Plateau, uranium bearing phosphorites may prove to be important. All marine phosphate beds tested for radioactivity have been found to contain significant amounts of uranium, which is generally in proportion to the phosphate content. In the phosphoria formation of Idaho, Montana, and Wyoming, an inverse ratio seems to exist between uranium and carbonate. In Florida, only the "land-pebble" type of phosphate deposit is of marine origin and is the only one known to contain significant amounts of uranium.

Most of the uranium in these deposits appears in the minerals fluorapatite or collophane in which it probably replaces calcium. Although it means mining grades of 0.01 to 0.03 pct U_3O_8, enormous tonnages may make this a reasonable source of uranium.

Comparatively low concentrations of uranium in vast tonnages of carbonaceous and bituminous shales have been known in many parts of the world for some time. Our best bet for production from this type of deposit in the United States, seems to lie with the Chattanooga formation which covers large areas of Tennessee and Kentucky. Thousands of square miles of this formation contains an average of 0.008 pct U_3O_8. In such quantity, this formation may one day be mineable. The mineralogy of the uraniferous black shales has not been completely solved yet, and no uranium minerals are identifiable in most cases.

Placer and lacustrine deposits are generally considered negligible sources of uranium production.

Developing U.S. Uranium Industry

Production of uranium in the United States today has reached a rate that was considered impossible, even as late as 1947. The Atomic Energy Commission feels that this achievement substantiates the policy that domestic uranium production can best be developed by private enterprise working for a profit.

Practically all present uranium mines in the country were the discoveries of private individuals or companies. All mining has been done by private enterprise. Money to back uranium mining ventures has been raised on the same basis as for any other mining operation. The only two departures from standard procedure are (1) the phenomenon of radioactivity to help detect the ore, and (2) the role played by the U. S. Atomic Energy Commission.

Encouragement and assistance are the keynotes of the AEC's raw materials program. Encouragement takes the form of setting a price for uranium ore at which the miner can make a reasonable profit. There is also a bonus of $35,000 as an added target to encourage new discoveries, and a transportation allowance to help defray the expenses of long hauls to the mills. These incentives effectively put more prospectors in the field looking for uranium than the AEC could hope to hire.

Other efforts include the publishing of volumes of information that might prove of aid to the prospector and arranging for laboratories at various points in the country to assay samples sent in by prospectors at no charge.

In the field the AEC has taken on both long and short term exploration projects. Through its contractors, the AEC does a great deal of exploration beyond the scope of the individual. A tremendous drilling program, for example, has not only eliminated vast areas where search would prove fruitless, but indicates the more favorable areas for local reconnaissance. As a result, prospectors' efforts can be concentrated and time lost in hopeless search reduced.

Not of such direct assistance to the man in the field, but of strong future possibilities, is the long range job of piecing together the story of why uranium is deposited where it is. This job of deduction on the basis of geologic data found so far, will one day be useful in determining the possibilities of finding ore in a relatively unexplored area, before an expensive drilling program is launched.

The mechanics of uranium deposition is being investigated for whatever light it may throw on the problem of where to look for uranium. Clues are also being sought in the fields of geochemistry and geobotany. The importance of uranium makes it imperative that no exploration methods be overlooked.

Open-Pit Forum

Modern Equipment

Cuts Costs at Bagdad

by ERNEST R. DICKIE

IN 1945 the Bagdad Copper Corp. decided to change from block caving to open-pit mining. By early 1948 the conversion was completed and production was increased from 1500 tons per day to 4000 tons per day. Open-pit mining costs decreased approximately 40 pct from the cost of producing ore by the underground method.

At present one P & H model 1400 all-electric 4½-yd shovel and one P & H model 1055 Diesel 3-yd shovel are used continuously for stripping. One 2½-yd Northwest shovel handles the ore. Delivery of a new P & H 1055 electric shovel for stripping is expected this month.

Blasthole drilling is performed with two Bucyrus model 22 and two Bucyrus model 27 churn drills.

Ore and overburden are hauled with the following equipment: 2 model E-40 Tournarockers, 2 model 140 Dart 20-yd trucks, 4 model 140 TC Dart 20-yd trucks, 6 model 15 TD Euclid 16-yd trucks, 4 model 54 TD Euclid 16-yd trucks.

The Tournarockers, in the past, did not prove satisfactory due to numerous breakdowns which were time consuming in waiting for parts and making repairs. However, the LeTourneau Co. has recently furnished us with two new pulls equipped with the Allison engine, Schneider torque converter, and Tournamatic transmissions. The two new machines have a capacity of 33 yd and are doing a good job, although they have been in service only about a month.

Seventy pct of the lost time for the two Dart 140's has been due to the Hall-Scott butane motors. Service and inability to obtain parts has caused most of the lost time on these two units. Installing Buda DC-1125 motors in place of the Hall-Scott motors is being studied. This model Dart is equipped with a 20-yd body and has the sprung rear axle. The tire mileage is 30 pct more than on the dead-axle type truck.

The six Euclid 15 TD 16-yd capacity trucks have worked very well. The operating availability of these trucks is about 70 pct average for the last two years. The over-all cost per ton of material hauled is a little high in comparison with trucks having rear springs and torque converters. These trucks are powered with Buda DC-1125 motors.

The four Euclid 54-TD trucks are the same as above except that they are equipped with rear springs. Operating availability is the same as the Model 15 TD.

The four Dart model 140 TC trucks are doing a good job. They are powered with Buda DAS-1125 supercharged motors and equipped with twin-disc, three-stage torque converters with Fuller 1220 transmissions. These trucks have 20-yd capacity bodies. Spring breakage and motor cylinder head cracking has caused some lost time. This trouble is being corrected. The Dart Co. has replaced the springs with a new design and the Buda Motor Co. is replacing the heads with new heads constructed of a higher grade of material.

The twin-disc torque converter is doing a wonderful job. The trucks negotiate the steep grades fully loaded and without shifting gears and return down grade without using the brakes. The grades from shovel to crusher bin or waste dumps vary from level to 16 pct. Torque converters will revolutionize the heavy off-highway hauling equipment because they will reduce maintenance cost to a new low. However, fuel cost will increase about 10 pct.

As a comparison the following costs per ton of material hauled at the Bagdad pit for 1950 and the first three months in 1951 are submitted:

	EUCLID 15 TD	EUCLID 54 TD First Quarter 1951, Only	DART 140	DART 140 TC First Quarter 1951, Only
Labor	$0.0163	0.0188	0.0185	0.0169
Taxes	0.0006	0.0006	0.0007	0.0007
Vacations and Bonus	0.0007	0.0001	0.0007	0.0002
Tires and Tubes	0.0195	0.0096	0.0156	0.0030
Lubrication	0.0028	0.0024	0.0039	0.0035
Miscellaneous	0.0069	0.0066	0.0126	0.0043
Maint. and Repairs	0.0231	0.0167	0.0396	0.0081
Ind. Insurance	0.0018	0.0013	0.0018	0.0011
Fuel	0.0075	0.0089	0.0120	0.0087
Total	0.0789	0.0681	0.1044	0.0465

The Euclid 54 TD models and the Dart TC models have been in service only about five months. It is reasonable to expect costs to increase after a year or more service.

Ten Buda DC-1125-240 hp and four Buda DAS-1125-350 hp motors have been installed at Bagdad. The DAS motors have run only about 2000 hr to date. Some cylinder head trouble was encountered in the beginning. Six of the DC-1125 motors have been in service about 2½ years and four in service about six months. Following is the hours run before first overhaul on the first six motors:

Date in Service:	Hours Operated Before Overhaul
Nov. 13, 1948	5083
13, 1948	6973
13, 1948	7068
13, 1948	5049
Apr. 26, 1949	7319
26, 1949	6853

Three of the above motors have been overhauled the second time. The hours operated before the third overhaul are as follows: 3490 hr; 5705 hr; and 3716 hr.

MR. DICKIE is General Manager, Bagdad Copper Corp. and an AIME member.

EMPLOYEE TRAINING

Reduces costs, increases labor efficiency at Utah Copper.

by HOWARD B. GUNDERSEN

CURRENTLY the mining industry faces the twin tasks of producing metals in the largest possible amounts and doing it with a dwindling and less experienced labor supply. A manpower shortage during this emergency appears inescapable. It therefore becomes necessary to develop the highest possible efficiency.

Employee training is a concomitant of economical, high production. Training keeps employee morale high, reduces waste, improves skills, and increases production without speed-up or overload of workmen or supervisors.

Training at the Utah Copper Div. of Kennecott Copper Corp. is defined as "a planned technique of imparting habits and skills to employees." Training is required to impart, at minimum time, cost, and effort, such skills and habits as are required to do a job or perform duties well. This applies to any occupation in industry, including the work of supervisors and top management.

It is necessary to call on many men in the various departments, mainly supervisory personnel, for detailed information for training course content. These men become the instructors after learning the instruction process. This procedure, though most effective, involves a lengthy and sometimes difficult orientation program for the potential instructors. Training is made effective with visual aids and demonstrations, it is modern, practical and applicable, it is developed and taught by employees for employees.

Some Kennecott employees were skeptical of formal training, fearing loss of their jobs because classes might be too difficult for them. After initial courses are completed, showing how training helps them perform their jobs better, more safely, and more easily, both supervisors and instructors received better cooperation. Men often commented that classes were too short.

There are five major types of training courses given:

(1) Occupational Refresher Training
(2) On-the-Job Training
(3) Apprentice Training
(4) Supervisory-Personnel Development
(5) Safety Training (in all courses)

Occupational Refresher Training—This course is designed to refresh the minds of men who may have been working on the properties for many years. It also includes remedial training for workmen to help change faulty work habits and develop new skills in the job.

First, a complete analysis must be made of each payroll job for which refresher training is to be given. An analysis of this type must include the details of everything a man must *know* and *do* in order to be proficient in his work. Such an analysis is shown in Step 1.

After completion of an entire detailed analysis, a topical outline is drawn from it to show the phases of training that must be covered. The topical outline eliminates all parts of the job that are common knowledge, or knowledge in use frequently enough to be known by all men. It also emphasizes the technical or "know-how" phases of the work. The topical outline is shown in Step 2.

From the topical outline a teaching schedule is made. This shows the order of presentation and the subjects to be covered. The final step is to develop a lesson plan. This plan sets down the objectives of each particular class period, the training aids needed, the information sheets necessary, and last of all, an outline of the things the instructor must *know* and *do* while carrying on his classes. This

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This article is condensed from a Feb. 1951 Annual Meeting paper by Mr. Gundersen.

lesson plan aids in reducing failure on the part of the instructor, through forgetfulness or poor planning. A sample lesson is shown in Step 3.

The lesson plan offers a step-by-step guide for the instructor, and although it is made up in considerable detail, it still affords the opportunity for free class discussion so essential to this type of training. The success of this discussion still depends on the leader or instructor.

On-the-Job Training—The purpose of this is to follow up and assure the success and application of the refresher courses, and also to aid new men in learning the basic techniques and methods, and acquiring the skills they must have before a refresher course can be of any value to them.

The facts are that job training covers a wide range, from one to two hours required to break in an employee on a simple, repetitious job, to the months and even years of training needed to teach a highly skilled trade. While much job knowledge is passed along informally from one employee to another in the working group, systematic instruction is usually more economical and effective.

Generally speaking there are three different levels of On-The-Job Training:

1. *The highly organized type* of program which may take the form of apprenticeships, including the work that trade and technical schools can do in providing related instruction. These programs are usually conducted or administered by special instructors or training specialists.
2. *Planned on-the-job training,* done on the job by the line supervisor within his own unit, with the assistance of the Training Section in the company to advise on "how to do it."
3. *Job rotation,* which is primarily incidental job experience and meeting needs on the spot as they arise. This is basically an unplanned method.

The Utah Copper Division is attempting to follow the program indicated in item No. 2. To raise this from the third level, the unplanned method, to the second or planned program level, requires support from all levels of management. It also requires the understanding on the part of management that the program cannot be thrown together overnight, nor can it be designed to meet a single on-the-spot need. The situations it aims to improve or remedy have probably been accumulating over the years. It must be considered a blueprint for the planned development of men. The policy of promotion from within, especially when seniority plays an important part, makes training imperative.

The On-The-Job Training program is conducted entirely on a departmental basis. The detail incident to the training of workmen is handled by the job supervisor. In this program the Training Section gives the supervisors help in determining *what to teach* and *how it can be taught effectively.* A planned program is arranged so that the supervisor is able to effectively handle on-the-job training for his own men.

Apprenticeship—This is a traditional method of training and today it involves labor contracts, wherein provisions are usually made for joint apprenticeship committees, schedules for work experience, related-technical instruction, promotions, graduation, and other standards.

Much of the success of this type of program depends on the plan of apprenticeship adopted, the organization that is effected, and the cooperation that exists in the joint apprenticeship committee composed of representatives from management and labor. The plan sets up the standards to be followed in the apprentice program. It outlines the qualifications that must be met before entering apprentice-

STEP 1 - Analyze each job on payroll.

PAYROLL JOB: Machine man (drilling)

DIVISION: Drilling with D A 35 Drifter

DEPARTMENT: Drilling and blasting

THE JOB: Collect and assemble all necessary drill equipment

KNOWLEDGE REQUIRED

Key Points – Hazards – Safe Practices – Timing – Feel Rules – Regulations – Policies – Practices – Procedures

1. What equipment is required.
2. Where equipment is located.
   a. When obtained from eating shacks.
   b. When stacked on level.
3. How to load equipment on push car when necessary to move any distance, or on speeder when to be moved to another level (higher level).
4. How to get approval of switchtender or flagman to use track. Must observe and obey flagman's and switchtender's signals for control of traffic.
5. How to remove push car from track and distance it must be away from track.
6. Proper lifting procedures and safety precautions in transporting equipment.

THE JOB: Make grade for drilling machine set up, when necessary

KNOWLEDGE REQUIRED

1. Make certain that bank has been trimmed of all loose rock.
2. How to get grade as low as possible for most desirable drilling angle.
3. Grade must be of sufficient width and depth so machine is well balanced.
4. How to construct trail when necessary to facilitate movement of equipment.

THE JOB: Set up and align machine

A. Connect air hose

B. Connect water hose

KNOWLEDGE REQUIRED

1. How ties should be set on grade in proper arrangement for tripod.
2. Procedure for setting tripod on ties.
   a. Two-man operation.
   b. Proper procedure and safe practice in carrying and placing.
3. How to place and drive spikes to hold tripod in position.
4. How machine is set on tripod.
   a. Two-man operation.
   b. See that clamp is open before moving machine.
   c. Safe practices in securing machine on tripod.
5. Make sure that pressure tank is full of water and that lid is securely fastened—90 psi in tank.
   a. Safety precautions in removing pressure tank lid.
   b. Safety precautions in melting ice and heating water in winter.

STEP 2 - Make topical outline of training coverage.

DRILLING

A. **Drilling toe holes (D A 35 Drifter).**

1. **Preparation**
   a. Equipment and supplies needed.
      (1) Procurement.
      (2) Transportation.
   b. Bank and grade conditions.

2. **Set-up and alignment of machine**
   a. Grade.
   b. Alignment and angle of machine.
   c. Supply system for water and air.
      (1) Safety precautions—winter and summer.
   d. Lubrication checks.

3. **The machine**
   a. Construction — general, what it is.
   b. Lubrication.
   c. Air.
   d. Water.
   e. Maintenance.
      (1) Chuck bushings.
      (2) Drill shank.

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ship and the procedures followed as the apprentice moves through his extended period of training, both on-the-job and the related technical instruction which supplements the work experience.

Supervisory-Personnel Development — Supervisors must be trained correctly in the handling and development of workers. The approach to supervisory training should be to develop men whose aptitudes give promise of ability to convey to employees the correct impressions of company policies, plans, regulations, and operations. As effective management representatives, they should also be able to interpret and report to top management conditions, problems, and suggestions effecting policy changes or determination. It is essential also that the training develop leaders who have an understanding of and regard for the proper working relationships with people.

The plan provides for conference outlines of subjects which are set up in three groups:

(1) "Basic Material For New Supervisors" equips them with techniques and methods or mechanics to perform new duties as efficiently and effectively as possible.

(2) "Standard Subjects For Experienced Supervisors" serves as a follow-through in the basic conferences and should increase the skill and improve the performance of supervisors on the job.

(3) "Advanced Subjects For Supervisory Development" broadens supervisors and prepares them to assume further responsibilities.

Supervisory personnel development may be planned by levels, by departments, by years of experience, or by total groups. The level of training planned in all cases should match the qualifications of the groups in training. A preliminary survey of the supervisory force will indicate the level of training which can be attempted.

Safety Training—Woven into all of these training programs is the study and application of safety practices—the safe way of doing work. This is emphasized and re-emphasized and every effort is made to get all employees to think and act safely under all working conditions and job situations.

The slogan, "Know The Truth and Be Free" has been adopted. A search for truth permeates the entire program, since workmen who know the truth are not encumbered by ignorance and confused by rumors, misinformation, and its accompanying dissatisfaction and lowered morale. The training section searches out the truth of how to lay a railroad track, how to handle an air brake system, how to drill a hole into the bank, and all other truth that will help put more ore into cars and through the mills in a safer, more productive, and easier manner.

Thirty minutes of each session for six of the meetings in each refresher course, is devoted to a discussion of the basic economics of the American business system.

To help make training effective, the instructor demonstrates physically as much as possible, using ties, rails, tools, drilling machines, welding equipment, parts of machinery, mock-up boards, models and other materials common to each specific job. These are brought into the classroom in the exact form in which they are used on the job. Photographs or drawings are made of all other materials necessary to effective instruction and then mounted on 3½x4-in. slides. In addition to the demonstrations and slides many films and film strips have been used. At first it was necessary to acquire films that had been made by other companies. Now some are being produced by the company.

As a supplementary part of all training at Utah Copper Div., Department of Mines, effective use has been made of occupational tests. As an aid in the selection of persons qualified to advance into positions requiring higher skills, six mechanical tests are given. For example, before a man can become a brakeman he must:

First, Pass a physical eye and ear examination; *Second*, Pass the battery of six aptitude tests, with a total average of 60% or better; *Third*, Pass the technical test on the orientation course for brakemen; *Fourth*, Get a rating of good or better on performance during a ten-day student training period on-the-job.

After satisfactory completion of the above requirements, qualified candidates are selected on the basis of *seniority* while disqualified candidates return to their previous job status.

This combination of tests is a long step forward in helping management to choose the best qualified men for jobs to be filled by advancement. The tests which are standard and in use by many industries, are administered impartially. Most of the unions have been cooperative in accepting the results of the tests, not insisting on seniority alone as the determining factor in advancement.

The program is not perfect, nor are the methods infallible. The engineer's work can usually be measured in tangibles with the aid of accurate tools or devices, but it is difficult to apply an accurate scale to measure results of industrial training. Both top management supervisors and wage earners developed and executed the program and the industrial training men have acted sometimes as councilors, sometimes guides, and sometimes merely "chalk boys" to write down good ideas.

STEP 3 - Prepare lessons like this sample on hole springing.

LESSON FOUR—Springing.

OBJECTIVES:

1. To teach or refresh the men on procedures and safe practices to follow in springing holes.
2. To give the technical information or "know why" required to properly handle explosives, loading pipes, tamping sticks, etc. and to do other jobs in getting the right kind of a hole for loading.

INSTRUCTIONAL MATERIALS:

1. Slides
2. Warning flags
3. Loading pipes
4. Tamping sticks
5. Dummy cartridges
6. Dummy caps
7. Friction tape

Teaching Points

Review Previous Lesson and Introduce This One – Springing

I Points Discussed in the Previous Lesson:

A. Bank Trimming.
   1. Reasons
   2. Benefits

B. Trimming Work.
   1. Procedures
   2. Safe practices

II Steps in Getting Ready and Materials Needed in Preparing to do the Springing Work. List on the blackboard the materials needed.

A. Materials.
   1. Loading pipe
   2. Loading sticks
   3. Buckets (2)
   4. Whistle for air line
   5. Friction tape
   6. Powder
   7. Primers
   8. Shovel
   9. Flags
   10. Hammer

B. Transportation—safe practices.
   Show slides of ore cars and push cars loaded with powder No. 40 and 41.
   1. Ore Cars
   2. Waste Cars } Emphasize
   3. Push Cars
   4. Flagman to protect push car—while loading, around bends.
   5. Do not haul powder and primers together.
   6. Do not haul powder on electric locomotives, etc.
   7. Handle with care—do not throw or handle roughly.
   8. Where powder can be stacked or left on the level.

C. Safety precautions around magazines.
   Show slide: Powder magazine, No. 43.
   1. Do not make up primers in or near magazines or around any quantity of explosives.
   2. Keep magazine clean—free of paper, loose powder or any inflammable material.
   3. No open or exposed lights.
   4. Magazine must be kept locked.

D. Placing of warning flags.
   Show slide: Warning flag No. 44.
   1. Near edge of bank
   2. In upright position
   3. At limits of springing operation

   Ask questions:

   a. What is the proper procedure in placing warning flags?

E. Whistle—Placing and operation.
   1. Springing

There has been a noticeable decrease in maintenance. In the drilling department there was a reduction of 24½ pct in repair parts cost per ft during the first nine months of 1950 in comparison with the same period in 1949. After the 12-hr refresher course in drilling and blasting, the footage drilled increased 6.7 pct and the holes loaded increased 10 pct per man-hr.

During the occupational refresher courses, new operating rules were drawn up and adopted by each department. The "days pay" employees and the supervisors, meeting in separate groups, participated in improving and adopting these rules. This participation helped them to feel that the rules belonged to and should be administered by every man in the crew, and resulted in improved operations.

In the operating and maintenance departments material has been saved by informing the men of the cost of waste and appealing to them to use materials wisely. Angledozer operators are more careful not to cover material or run over it needlessly. In the refresher courses, tables have been prepared showing the cost of time and materials used in properly maintaining the equipment. Opposite this column is shown the cost of neglect. The cost of neglect is so much greater that it is startling. The evidence is conclusive and the operator cannot help but be convinced that proper attention to maintenance is his responsibility.

The men in the refresher classes have helped improve various practices by offering their own ideas.

Approximately eight hundred men work in the track department at the mine on two regular shifts and one intermediate shift. These training sessions have provided some of the few opportunities for the average track department employee to talk with his department head.

Where two departments were cooperating on any work, for example, the mechanical department and the track department, it was possible to call representatives from each and have them explain how the work could be done to the best advantage. Providing for this coordination gave better interdepartmental morale. Mechanics, supervisors and others who have not yet attended training sessions have expressed an appreciation for this fact. When the men came into the class they were good practical men as far as the *do* part of these jobs was concerned. After training, they had technical knowledge to understand the *why* of their practices.

Accident frequency has been reduced since the inauguration of the training program. Using the standard formulae the figures show that the accident frequency rate in the mining department decreased 11.5 pct in 1950 as compared with 1949.

It is certain that the foremen who handle these classes, including the preparation of the course content, are much better foremen as a result of this training activity. It gives them experiences which are applicable and vital in becoming the best supervisors on the job.

If seniority is to remain in the contracts as a factor in promotion, this alone is objective evidence of the reason why training is essential. Much of this may have to be done on the job, some in the classroom. If men are to move into positions because of seniority or even after qualifying examinations, special attention must be given to their training, or the efficiency of the operation will be impaired and eventually costs may ascend to the point where operations cannot continue.

WIRE ROPE

— how it's made
— how to take care of it

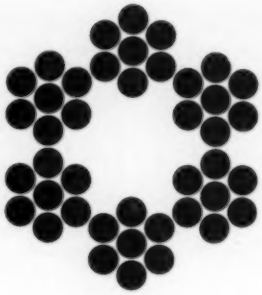

Fig. 1

by CHARLES M. HAAS

WHEN minable ore has been located, the problem of mining is synonymous with the problem of movement—movement of men and equipment to mine the ore, and movement of the ore from the earth to the mills. In slusher drifts and shafts, on shovels and dragline excavators, on churn drills and bulldozers, wire rope is essential to the transportation of men, ore, overburden, and equipment.

Although a casual glance creates the impression that all wire ropes are alike, there are crucial differences between ropes. Strand diameter, number of strands, weave, core, and resistance to corrosion all decide the type of job a wire rope can do, and where and how long it can do that job. These factors are, of course, the responsibility of the rope manufacturer. Beyond this, he can extend his function into the mine itself by advising users on the use, care, and maintenance of these sinews of the mining industry. This article, then, covers both the manufacturing and end-use aspects of wire ropes.

Types of Wire Rope

Resistance to abrasion and bending fatigue are two major criteria in wire rope design, and a sound basis on which to compare the various types of rope available to the mining industry.

Fig. 1 shows 6x7 wire rope, made up of three component parts, the smallest of which are the individual wires. A number of these wires are laid around a core wire to make a strand—the second component part. A number of strands, usually six, are laid around a core, the third component part, to make a wire rope. In this case the core is fiber. Notice that the wires in this construction are relatively large. They will withstand a lot of abrasion before wearing through, but their size limits the amount of bending over small sheaves that they can stand. They will fail from fatigue sooner than wires of relatively smaller diameter.

Nine outer wires over nine inner wires over one core wire constitute one construction of 6x19 Seale (Fig. 2), named after its inventor, Thomas Seale. The outer wires are smaller than in the 6x7 construction, hence they will withstand less abrasion but more fatigue bending. This is a common construction for slusher service.

One step beyond the 6x19 Seale is 6x21 Seale with an independent wire rope core (Fig. 3). It has 10 outers, 10 inners and a core wire. It is more flexible but not quite as rugged, and features an independent wire rope core. This type of core is used when more strength is needed (it is about 7½ pct stronger than a fiber core rope of the same construction), however, it is more often used to counteract crushing and distortion. It's recommended for example, in slusher service, because with the comparatively small drums and the severe overwinding, a fiber core would soon fail and the rope would flatten and be crushed out of shape.

Contrary to popular opinion, IWRC ropes are not stiffer and ordinarily do not need larger sheaves than fiber core ropes. Actually, due to the increased pressure on the rope when relatively small sheaves are used, IWRC's are selected to prevent premature collapse of the rope.

More flexible than any of the previous constructions but not resistant to as much abuse from abrasion, crushing, etc., is 6x25 Filler Wire (Fig. 4). This construction has 12 outers, 6 inners, 6 small fillers and one core wire. It is the happy medium between abrasion resistance and resistance to bending fatigue, and there is more of this construction made than any other kind. "When in doubt recommend 6x25 Filler Wire," has become a stock phrase.

The construction used for hoist ropes on large shovels and draglines as employed in open-pit mining is 6x41 Filler Wire (Fig. 5). This construction is made up with 16 outers, 8 small fillers, 8 inners, and one core wire. This rope design is generally confined to larger diameters only. In small-diameter ropes the outer wires would be too small to be of practical importance.

Triangular core wire constructions are exemplified by 6x25 Type "B" Flattened Strand (Fig. 6). Twelve inner wires surround the core wire and twelve outers. The center of the radius is the center of the rope—this means that all of these outer wires will bear in the sheave groove. This is called flattened strand rope. One disadvantage is that because of the triangular shape of the core wire, the core wire may break up into short lengths in service and cannot be considered a strength member of the rope, but merely a filler.

To overcome the disadvantage of the triangular core wire three wires are laid parallel for a core in the 6x27 Type "H" Flattened Strand (Fig. 7). This construction has proved itself in shaft-hoist service. The wearing surface is fully 100 pct greater than in round-strand rope. It will withstand more crushing

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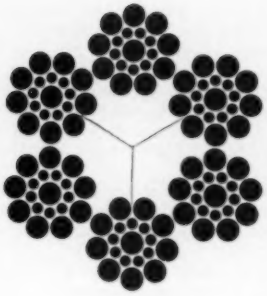

Fig. 2

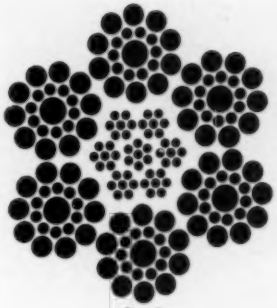

Fig. 3

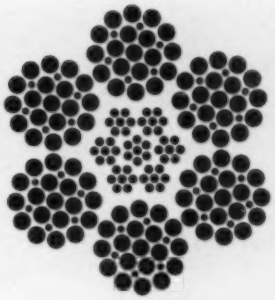

Fig. 4

on the drum and is approximately 10 pct stronger than round-strand rope.

Rope Weaves

In Fig. 8 the wires in the strand of the rope at top rotate in a direction opposite to the rotation of the strands in the rope. In consequence, the outside wires in the finished rope are parallel to the center line of the rope. This rope could have been made "left lay," in which the strands would have rotated to the left while the wires rotated to the right. This is called a "regular lay" rope.

John Lang decided to lay wires and strands in the same direction and produced the "Lang lay" rope shown in the bottom view. With both rotating in the same direction the wires are not parallel to the core but cross at about 36°. Lang lay has certain advantages. The wires present more surface for wear, the rope will withstand more crushing action, and it is also more flexible. However, there is a disadvantage—with wires and strands both rotating in the same direction the rope has a marked tendency to untwist. It should not be used unless both rope ends are always attached. Examples where it can be used are shaft ropes and dragline ropes.

Preforming is another important part of wire rope design. Its importance can be demonstrated by removing the serving or seizing from the ends of samples of preformed rope and ordinary rope, and noting the results. Rope that is not preformed will literally fly apart when the seizing is removed. Preformed rope remains intact. Other advantages of preforming are:

1—Increased bending fatigue properties, because the rope is stress-relieved.

2—Better spooling on drums because it is not cranky and wild.

3—Easier handling—it needs no seizing and will reduce the cost of installation.

4—When a wire breaks there is no "wickering." This makes it safer for handling.

5—The stress-relieved wires will wear much thinner before they break from bending.

However, since the wires lay in place rather than "wicker," inspection of preformed ropes is more difficult. It is often hard to find broken wires. Preformed rope also costs a little more than non-preformed rope but in many cases it is well worth the additional cost.

Wire rope is probably more appreciated in underground than in open-pit mining. Men's lives underground are more often dependent on properly maintained wire rope, and it is used not only in actual mining (slushers, tugger hoists, etc.), but also in hoisting the ore to the surface.

In Michigan there are special problems in the design and manufacture of hoist ropes. The shafts are usually deep enough to require multiple layers on the drum. This is a good application for Lang lay rope—it will better withstand the punishment administered by multiple winding. In the past few years Lang lay flattened-strand rope has been used on a number of installations in this district, and, as expected, it has done exceptionally well. This construction presents much greater wearing surface and will better withstand the crushing on the drum.

The most serious problem is that of corrosion. The shafts are invariably wet. Furthermore, the ore dust cakes on the rope and it is difficult to relubricate the ropes during their service life.

In order to combat the problem, a different type of lubricant is being used during manufacture. It is a lead naphthanate base lubricant, with a rust inhibitor added, and is very tacky. It has been tried on rotary and cable tool drilling lines, coal mine

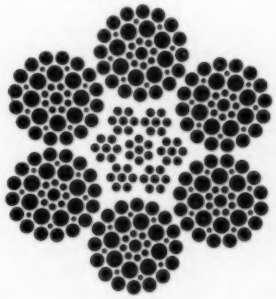

Fig. 5

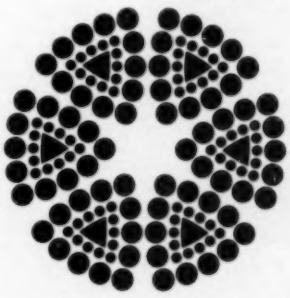

Fig. 6

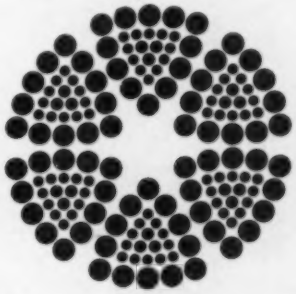

Fig. 7

Fig. 8—In the "regular lay" rope at top, wires rotate opposite to strand. Both rotate in same direction in "Lang lay" rope, below.

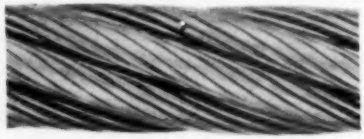

Fig. 9—Wires in this rope have undergone plastic deformation rather than wearing away.

Fig. 10—Top sample shows peening and some pitting. Lower sample shows no wear but is corroded.

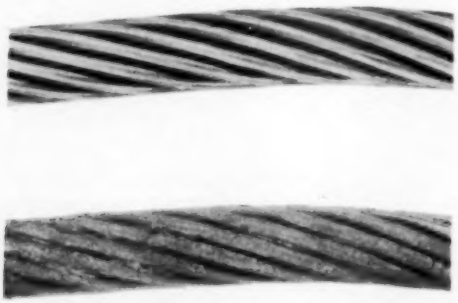

Fig. 11—Two strands from different portions of a rope taken from next to the core. No corrosion shows in strand, above.

shaft hoist ropes and on shrimp ropes (exposed to salt water). Good field reports were received, and the lubricant is being recommended for use in this district.

Zinc coated wires have also been tried as a means of combating internal corrosion, and the results have been encouraging. Zinc coated shaft ropes are now being recommended in localities where corrosion is particularly bad.

Figs. 9-13 illustrate the effects of corrosion on a shaft hoist rope that was used in the Michigan district. All of the photographs show different sections of the same rope.

Although the section shown in Fig. 9 may appear to be rather badly worn, the wires are merely peened from cold working. In other words they have undergone a plastic deformation rather than a wearing away. When this sample was tested, it developed a strength of 220,000 lb which is slightly above catalogue breaking strength.

In Fig. 10, the top sample shows peening action and some pitting. The lower sample shows no wear or peening but is severely corroded. In fact, this section of the rope did not travel over the head sheave. The upper sample developed 197,000 lb and the lower sample 194,000 lb.

Fig. 11 shows two strands removed from different sections of the rope. The view shown here is that portion of each strand that was adjacent to the fiber core. Note the absence of corrosion in the upper strand and its presence in the lower strand.

The same two strands with the outer layer of wires removed are shown in Fig. 12. The upper sample is in excellent condition. The poor condition of the filler wire, which has practically rusted in two, demonstrates fully the extent of the problem of corrosion.

A photomicrograph of the cross-section of three wires is shown in Fig. 13. The middle wire is an unused wire of the same diameter as the outer wires of this shaft hoist rope. The right hand view is of one of the wires that appeared to be worn. Actually it is peened. By the use of a planimeter it was determined that actually 99.3 pct of the original area is remaining in that wire. In other words the wires are expected to cold flow—were they made hard enough to prevent cold working during service they would be much too brittle.

The wire on the left is one of the corroded wires. The worn or peened surface is visible as is the marked effect of corrosion. The planimeter showed that this wire has lost 19.3 pct of its original area, principally as the result of corrosion.

One major problem in wire rope maintenance is that of relubrication during the service life of the shaft rope. The ore caked on the ropes complicates the problem, and moisture seeps through the caked ore. A light lubricant which will penetrate to the core must be used, because if a heavy lubricant is applied, it only serves to seal in the moisture.

Sometimes the question of socketed connections versus clipped connections is brought up. The use of sockets on shaft hoist ropes is not recommended. Due to the comparatively large mass of the socket any vibration in the rope is arrested quite suddenly at that point. This condition can cause a fatigue spot where failure may occur. This is the reason some mining codes give definite intervals for re-socketing. A thimble and clipped connection will dissipate the vibration less abruptly. Furthermore, this type of connection is amenable to inspection.

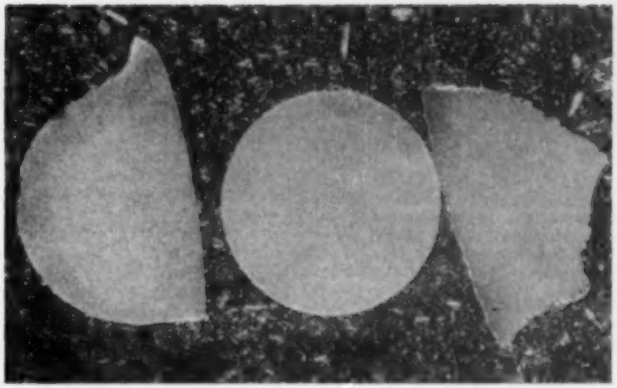

Fig. 13 (right)—Photomicrograph of cross-section of wires. Outer wires were in service for hoisting, middle wire was unused.

Fig. 12 (below)—Two strands from outer layer of wires illustrate corrosion problem.

Yet even with this connection it is recommended that the rope be cut off and reclipped periodically.

Slusher hoist operations are harder on wire rope than any other form of usage. Some of the factors that influence the life of these ropes are: Severe abrasion as the rope is pulled through the ore; bad winding on drums—cross winding plus overwinding; comparatively small drums; and terrific shock loading—The rope is slack and then under full tension by jerks.

Actually there is not much that wire rope manufacturers can do. There are only two variations on the usual 6x19 Seale—either a stiffer rope or a more flexible rope. A stiffer rope would have a fewer number of larger diameter outer wires which would better withstand the abrasion and also the cross winding on the drum. However, the men would object because they could not tie knots in the rope when it breaks. The larger wires would also fail sooner from fatigue because of the small drums.

A more flexible construction would better withstand fatigue failure but would probably fail from abrasion. Drum abuse is, in slushing, the most important factor. Trial use of a 6x21 Seale, Improved Plow, IWRC, Preformed rope has been suggested. This is an experiment only and as yet the results are not available. The 6x21 Seale, being a little more flexible and assisted by preforming might hug the drum better and result in somewhat less abuse. Improved Plow offers maximum tensile strength and now costs only slightly more than Plow Steel. It is 15 pct stronger than Plow Steel.

In open-pit operations rope applications are different from deep mines because the safety hazard is not so great. On excavating equipment some ropes are often used to destruction or certainly more nearly so than would be wise in case of a shaft rope. The two main applications are for shovels and draglines. Shovels are used to remove overburden and to load the ore. Draglines are practically always used for overburden.

The ropes used in open pits are hoist ropes, drag ropes and boom lines. These ropes are specialty ropes and it is the manufacturer's business to know the various makes and models of machines and to furnish ropes to best meet the operating requirements of each. It is also the manufacturer's job to recommend the best constructions on the various machines. The correct construction will vary with the rope diameter. As an example, on a small shovel 6x25 Filler Wire construction might be recommended for the hoist rope; but for a large shovel, the outer wires of 6x25 Filler Wire would be much too large so that 6x41 Filler Wire might be recommended.

On such equipment the prime consideration is cubic yards or tons of material handled.

Increased Rope Life

There are several points that might help to increase rope life. Some companies find it economical to turn hoist ropes and drag ropes end for end after approximately one-half of the apparent service. The advantage is analogous to crossing or switching the tires on an automobile. It is necessary to balance the advantages with the cost. Certainly it is sound from a common sense standpoint to change the wear points. However, it would be foolish to turn a rope end for end that has its worst wear right in the middle of the rope.

Lubrication also results in longer rope life. It is necessary to employ a lubricant that is light enough to penetrate so that the inside of the rope is also lubricated, for when a rope bends over a sheave the wires must slide one on another. These, then, are the basic facts of wire rope manufacture and wire rope maintenance. It is obvious that manufacturers are devoting careful attention to the problems of mine operators, while at the same time offering a wide selection of ropes in materials designed to offer maxium resistance to the twin destroyers of rope—abrasion and fatigue bending.

Books for Engineers

The Chemistry of Uranium. By Joseph J. Katz and Eugene Rabinowitch. Published by McGraw-Hill Book Co. of New York, 1951. 609 P. $7.25.—This volume is the first half of a comprehensive treatise on uranium chemistry. It contains a detailed summary of the properties of the element uranium, including its occurrence in nature, extraction from ores, and the physical and chemical properties of uranium metal. Binary compounds of uranium with hydrogen, oxygen, nitrogen, and the halogens, among others, receive extensive discussion, including methods of preparation and physical properties such as crystal structure, thermochemistry and volatility. A very large proportion of the material in this volume is based on the results obtained in the laboratories of the Atomic Energy Project, much of it not published before. In addition, all of the open literature has been critically surveyed and integrated with the results of the Atomic Energy Project studies.

Principles of Geology. By James Gilluly, Aaron C. Waters and A. O. Woodford. Published by W. H. Freeman & Co., San Francisco, Calif., 1951. 640 P. $5.75.—This book attempts to summarize some of the knowledge that geologists have won from the study of the earth. It covers such subjects as movements of the earth's crust, records of earth movement, stream erosion and deposition, deserts, the ocean and mineral resources of the earth. The authors have concentrated on the analysis of processes that are at work upon and within the earth, rather than to present a catalog of descriptive facts and terms. The development of stratigraphy is also outlined. Pictures, maps, and tables are used to illustrate the major points of each chapter.

A Mining Engineer's Survey Manual. By J. E. Metcalfe. Published for *Mine & Quarry Engineering* by Electrical Press, London, 1951. 341 P. 30s. Net. —This book has been written primarily for the engineer who wants details of methods and practical help in mine-surveying problems. Although as its title implies, it is a manual rather than a student's textbook, it should be useful in preparing the young surveyor for the problems he may encounter in the field. A knowledge of the principles of surveying is taken for granted and much of the material to be found in textbooks has been omitted. It covers such topics as underground surveying, surface surveying, stope-surveying and the theory of errors in surveying.

Stratigraphy and Sedimentation. By W. C. Krumbein and L. O. Sloss. Published by W. H. Freeman & Co. of San Francisco, Calif., 1951. 497 P. $5.00.—The purpose of this book is to assemble and integrate the facts, principles, and hypotheses bearing upon stratigraphy and sedimentation in a form that may be studied and assimilated in an efficient manner. The book is the outgrowth of a combined course presented by the authors at Northwestern University. It covers such subjects as stratigraphic procedures, sedimentary processes, sedimentary tectonics and paleogeography. This book is primarily concerned with the exposition and application of stratigraphic principles which appear sound in the light of these newer observational data.

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Diamond Drill Handbook. By J. D. Cumming. Published by J. K. Smit & Sons of Canada, Ltd., 1951. 501 P. $6.50.—In the main, this book covers the application of diamond drilling to the special conditions found in the Canadian PreCambrian Shield, with particular emphasis on the metal mining field. Applications to coal mining and oil exploration are referred to only briefly. It is intended for the engineer, and geologist, the student, the mine manager, the exploration company and the investor who wishes to understand the relationship of diamond drilling to exploration and mine developments and to evaluate drilling terms used in reports and in the mining press. The cuts, tables and sketches show, in many cases, specific installations.

Economic Mineral Deposits. By Alan M. Bateman. 2nd Edition. Published by John Wiley and Sons, Inc. of New York and London, 1950. 916 P. $7.50. —This book is divided into three parts, the first being devoted to a thorough but uncomplicated presentation of principles and processes. The remaining two sections treat metallic and nonmetallic mineral deposits with the greatest emphasis on the geologic phase of the subject. The war years brought many new mineral developments and changes, and these have been incorporated in this book. In response to many requests, the selected references at the end of each chapter have been expanded to a total of 41 pages, covering up to the end of 1949.

The Witwatersrand Gold Mines. By Paul Klempner, First Edition. Published by Paul Klempner, London, 1951. 307 P. 25s.—This book is divided into four sections. Section I covers general information on present mines and possible extensions, premium sales of gold, and uranium from Rand Mines. Section II describes estimating the gold content in the ore and covers such subjects as assay plan factor, pay limit of mines, and percentage of payability and claim. Taxation relief in the U. K. and taxation in South Africa are covered in Section III. Valuation in regards to life of a mine and valuation of the Witwatersrand Gold Mines are discussed under Section IV. The various Witwatersrand Mining Companies are listed with development results, ore reserves, production and operational results, and share prices for the companies listed.

Papers and Discussions of the Association of Mine Managers of the Transvaal. 1948–1949. Published by The Transvaal Chamber of Mines in 1950—Papers which were presented by authors on the subjects of exploitation, reclamation, ore and personnel transport, management, and ventilation and dust prevention of mines are given in this book. The paper given by R. H. MacWilliam on "Sinking No. 3 Shaft at St. Helena Gold Mines, Ltd." is covered in a special chapter and covers such topics as types of shaft to be sunk, surface and underground equipment used in sinking the shaft and description of sinking methods. Charts and illustrations are given covering the main points of this chapter. There is a chapter on, "A Few Problems in Mine Supervision" by W. F. Thomas. Mr. Thomas' paper stresses introducing the new worker, handling men within industry and remuneration for officials. W. E. Meyer's paper on "Rock-Drill Lubrication and Air Line Lubricators" covers such topics as the selection of a suitable lubricator, methods of testing it, lubricators which are operated by velocity pressure, and lubricators which make use of a plunger.

Geological Survey Bulletins of the State Geological Survey of Kansas. 1950—There are four main bulletins covered in this book. Bulletin 85 describes the geology and ground-water resources of Rice County, Kansas. The origin of Kansas Great Plains depressions and subsurface reconnaissance of glacial deposits in northeastern Kansas are some of the subjects covered in Bulletin 86. Oil and gas developments in Kansas during 1949 is covered in Bulletin 87. Bulletin 88 describes the geology and ground-water resources of Barton and Stafford Counties. Each bulletin has a map of section covered and illustrates by means of graphs and charts the main points of the chapter.

Developing Mesabi Orebodies Under Lake Beds

by James R. Stuart

AS the available remaining properties of iron ore reserves on the Mesabi Range are opened up for mining, the various properties located under lake beds are brought nearer an active status. The actual physical problems involved in stripping these properties do not act as a deterrent so much as the legal and political problems that are encountered.

When it is proposed to destroy a natural lake that has been used by the public for many years, much local as well as state opposition may be encountered regarding its destruction. Public hearings must be held and some adverse publicity is likely to result. The ownership of the ore under the lake and the rights of the abutting property owners must be settled, and protection from damage caused by a disturbance in surface and subsurface drainage is likely to be demanded by property owners some distance from the proposed mine area.

The Embarrass Mine, located near Biwabik, Minn., falls into this classification. A portion of the orebody lies under what was formerly Syracuse Lake, this body of water having been removed in the process of stripping the mine.

An additional problem in the case of a meandered body of water is the establishment of a meander line that can be projected downward as mining progresses to form the basis for a satisfactory division between lake bed and upland ore shipments for royalty purposes. Fig. 1 illustrates the complications encountered in maintaining these divisions. A balance point was agreed upon in the center of the lake to make an equable division of lake bed ore to the abutting properties. The entire lake bed has since been adjudged the property of Minnesota.

Lake Characteristics

Lake bed stripping problems with which this paper is concerned necessarily are limited to a specific type of lake, namely the glacial lakes of the Lake Superior region. One characteristic common to these bodies of water is a deposit of fine black mud or silt on the bottom, frequently underlain by a layer of impervious blue clay. This is also true of the muskeg areas of the region, which present almost identical problems as lakes in stripping.

The actual removal of the water and the lake bed material is a routine matter more or less standardized as to equipment, and the period of time required can be estimated easily on the basis of volume and capacity. More important than the foregoing is the execution of preliminary work, and above all, the timing involved. An account could be prepared based entirely on statistical and cost data which would give a very fair picture of the time required and cash outlay needed to effect the removal of a body of water preliminary to stripping the orebody. However, the real interest from the standpoint of the operator and the engineer who carry responsibility for completion of the job lies in the unexpected emergencies and the action of various materials involved in the stripping when the balance has been upset through diversion of water courses and the reduction of the lake level.

Runoff and Drainage

Lakes are located in natural basins that catch all the rain water and runoff water for a considerable area. Where a lake is involved having an inlet and outlet or a sizeable water course running through it, the drainage area may include a watershed covering many square miles. All available data then must be collected to supply a history extending over as many years for which information can be gathered on the flow of streams, annual rain and snowfall, and most important, the peak flows to be expected. Where the diversion of a stream around the stripping area is a part of the problem, this last factor is of great importance since it controls the cross-section to be selected for the diversion channel and the volume to be removed in its excavation, as well as affecting the hydraulic considerations to be met in the design of the completed channel.

Characteristic material in the overburden found at the Embarrass Mine is illustrated in Fig. 2.

Well Pumping

Pumping from the well holes was started well in advance of the draining of the lake. Fig. 3 shows a gradual lowering of the water table with no noticeable fluctuations during the period in which the lake was being dewatered. Unfortunately, because of tight ground, a maximum flow to the wells was not maintained. This retarded the rate at which the water table was reduced so that in the course of stripping the excavation soon extended below the water table, and the great bulk of the pumping was handled from a system of sumps in the pit itself. Any dewatering program projected by prepumping from wells, a glorified well point system, would have to be started well in advance of the stripping to be of any great advantage.

Preliminary drainage of the surface over the mine area is entirely apart from the actual elimination of the lake bed itself. Since the lake is what is called a perched water table because of the impervious character of the lake bottom, the adjoining surface may be dewatered below the surface of the existing lake and the flow will not be affected by the proximity of that body of water. This condition actually has been demonstrated through the establishment of a number of observation holes where a small churn drill was used to put down the holes and a 3-in. pipe was installed for taking water level

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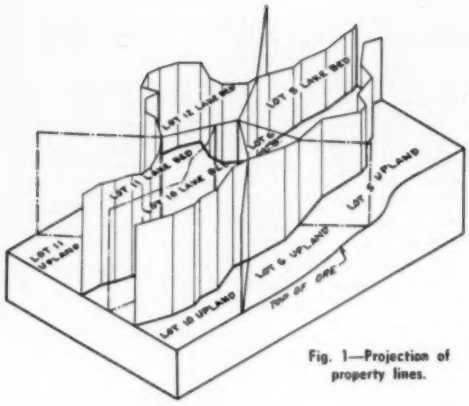

Fig. 1—Projection of property lines.

measurements. Water was pumped from a number of large diameter well holes put down with a rotary drill rig and using a bit diameter of 32-in. Deep-well pumps were used in dewatering from these holes.

Under natural conditions the surface of a lake is the water table. From the contact of the water with the shores, the water table in the ground slants upward roughly paralleling the surface. The first efforts to control drainage in the vicinity of the pit would be the establishment of ditches outside the perimeter of the proposed stripping area to catch surface runoff from rainfall and natural drainage and conduct it away from the mine.

A generalized cross-section showing effect of well and sump pumping on the water table is shown in Fig. 4.

Diversion Channels

Returning to the problem of stream diversion, construction of the diversion channel in itself tended to reduce the elevation of the ground water on that side of the pit area, since there was a flattening of the water table between the mine and the channel. A disturbing element here was the possibility that a pervious gravel layer might be cut by the channel, allowing the diverted water to enter the ground as a subsurface flow and find its way to the stripping area. However, no indication of this condition appeared in the pumping record after the stream was diverted.

As is true of many projects where climatic conditions are changeable and winter operating conditions severe, the timing of various projects eventually got out of step. Dewatering of the pit area was accomplished through the use of sumps. It became necessary to enlarge the pit area by dewatering the lake, and this in turn required a temporary diversion of the stream prior to completion of the diversion channel. A temporary diversion channel therefore was constructed along the east shore of the lake to accommodate the flow and allow dewatering of the lake. No noticeable leakage developed from this temporary channel into the pit area while it was in use.

The steps in water diversion before completion of permanent diversion channel are shown in Fig. 5.

Dewatering Lake

Since the lake had a maximum depth of only 20 ft, the head on the dewatering pump was not a problem. A centrifugal pump with a capacity of 3500 gpm was installed on the dike between the lake and

Fig. 3—Generalized cross-section showing effect of well and sump pumping on water table.

the temporary diversion ditch for this work. The same pump was shifted downward as the suction lift increased. The overall period required to pump out the lake was 19 days.

Ordinarily at this stage of the operation with the entire lake bed exposed, the supposition would be that the whole lake bottom, in this case approximately 30 acres, would present a surface of semi-fluid black mud. As it developed this condition was modified by the fact that the lake water, as it was pumped out, relieved the pressure against the bottom mud. When this balance of pressure was disturbed, the lake bottom mud started to creep and flow and followed the water to the low point in the basin. This fortunate tendency resulted in providing a stripping area of the original lake bed that contained a shallow layer of lake bottom mud that could be mixed with the glacial material below and was loaded out as normal stripping. A part of the deeper mud was bailed out by dragline and removed with bottom dump trucks. It was found that as the winter weather became colder, and subzero temperatures were the rule, the lake bottom material became very much less fluid, thus expediting its removal.

Subsurface Conditions

The condition of the glacial materials, both sand and gravel, directly under the lake bottom mud was very dry—definite proof that the lake water had not fed into the subsurface drainage of the area.

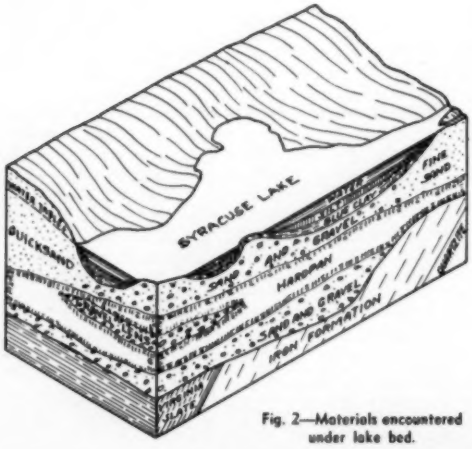

Fig. 2—Materials encountered under lake bed.

This again was a reassuring condition since deeper lakes were located both upstream and downstream from the mine. Leakage from either one of these bodies of water would have intensified the stripping problems.

A point to be noted was that in spite of the fact that the entire lake bed was stripped out and the elevation of the bottom of stripping was carried well below original lake level, the sump being 100 ft below this elevation at this time, the entire flow of the river was carried in a temporary diversion channel through the winter at the toe of stripping until it was turned into the completed permanent diversion in the spring of the year.

Quicksand Problems

A major feature in the early stages of stripping at the Embarrass Mine was the large area of quicksand that extended to a considerable depth before hardpan stripping was encountered. Lowering of the active stripping area required special treatment here since no means could be found to dewater the fine sand in advance of operations because of the steep gradient held by the water in the sand where a bank was opened up.

Power shovels were out of the question since the quaking sand offered no support for excavator or haulage trucks. Dragline equipment was substituted, and a main sump was established with a system of ditches leading into it. The initial lift was taken from the sump with the excavator standing on floats, and the material removed was cast back from the crest. This combination of sump and ditches dewatered a thickness of 5 to 8 ft of sand which was then loaded out into trucks by dragline, after which the process was repeated.

An operating problem of interest was the stubbornness shown by the quicksand when attempts were made to dig it with the dragline bucket. The saturated fine material was of such a livery consistency that when the bucket was pulled through it, water and very little sand was recovered. Bringing the bucket in on the ends of the teeth showed the same results. The technique finally developed was one of patience. The operator would let the bucket out to the limit of his reach, then allow it to sink slowly into the sand of its own weight before pulling it in filled with sand.

The most satisfactory arrangement found for pumping from the sump was to mount the pump units on floats with flexible connections to the pipelines brought down the bank. In this way variations in water level did not endanger the pumping units, and in the event of power failure dewatering could be resumed quickly when power was restored. Since advance of the project was entirely dependent upon keeping the water down, pumping units were kept available at all times with a capacity of twice the rate of pumping required to hold the water elevation static.

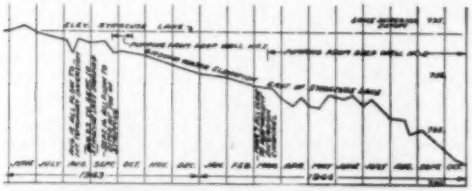

Fig. 4—Ground water elevations during diversion and pumping operations.

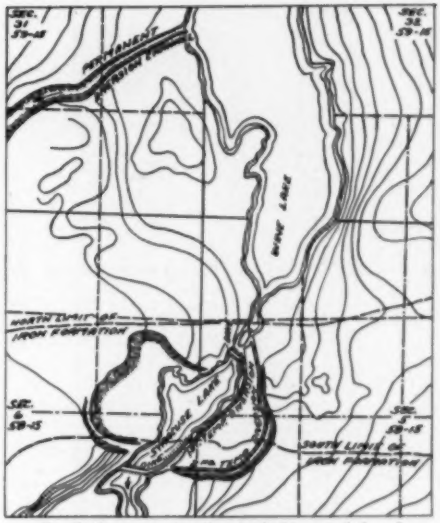

Fig. 5—Steps in water diversion before completion of permanent diversion channel.

Summary

The major considerations in developing orebodies that occur under lake beds would be:

1—Set up a schedule far enough in advance so that an orderly system of surface drainage controls would be operating prior to the start of stripping operations.

2—Where stream flow is to be controlled, removal of the channel to a permanent diversion location before operations were started would safeguard the work and would not tend to cramp the operation by forcing the use of a stripping plan that would make security of a temporary channel location a major premise.

3—The drilling of test holes to determine the type of material to be expected adjacent to the lake that is to be drained. This would serve two useful purposes. The holes would give a clue as to whether the ground could be predrained through the use of deep wells, and with a pipe casing installed, they would serve as observation points to measure the elevation of ground water during stripping and drainage operations.

The notes covered in the foregoing paper resulted from observations and experiences afforded by one particular mine, the Embarrass Mine on the eastern part of the Mesabi Range. They have of necessity been reduced to generalities that would apply to any similar project.

It is interesting to note that a pump operating at an average discharge of 3000 gpm would remove a volume of water equivalent to 7000 cu yd in an 8-hr shift. When the volume of a lake is regarded as displacing an equal volume of surface stripping, the simplicity of pumping, with no dump area necessary and a minimum amount of equipment and labor required, presents intriguing possibilities for economies.

Adsorption of Silver Ion by Sphalerite

by A. M. Gaudin, H. R. Spedden, and M. P. Corriveau

A preliminary study of silver ion adsorption by sphalerite in ion exchange column with influent electrolyte marked with radiosilver is described. Rapid ion exchange occurs at first followed by slow reaction controlled perhaps by solid state diffusion. One experiment with radiocopper instead of radiosilver is reported briefly.

IT has been known for many years that sphalerite is floated after it has been activated by a metallic cation, particularly copper.[1] The activation of sphalerite by copper is known to be an exchange of an atom of copper for an atom of zinc at the surface of the sphalerite.[2, 3] It has been estimated from various guesses of the available mineral surface that the depth of the copper-bearing coating is of the order of thickness of one atom. However, the exact mechanism of the activation process is unknown.

A number of metals other than copper act in the same general manner.[4, 5] In particular, it has been known that silver replaces zinc at the surface of sphalerite. As copper is usually divalent, whereas silver is monovalent, it may well be assumed that there are differences, perhaps major differences, in the detailed scheme of activation by these two cations. Furthermore, since silver has unusual photoelectric properties and may be a contributor to the fluorescence of sphalerite, a study of its activating mechanism might open up some interesting avenues for exploring these other phenomena.

The choice of silver as an activator of sphalerite was suggested also by the fact that its radioactive tracer, silver 110, is particularly convenient in that it has a long half-life and is energetic enough to permit counting through a counter window. The experimental technique selected, therefore, included the preparation of solutions of silver nitrate containing a proportion of active silver nitrate sufficient to give convenient counting data.

In further considering the method to be used, a desirable choice seemed the use of batch experimentation in which a given solution was allowed to act on a certain lot of mineral for a given length of time at a given temperature, this period of mutual reaction being followed by analyses of the separated solid and solution. But an alternative method seemed more attractive. This is the method now so familiar to the users of ion-exchange resins, which was first made famous by the Russian chromatographer, Tswett.[6-8] It consists in forming the mineral into a porous column through which the solution is allowed to flow at a constant rate. The usual method of allowing a batch of solid to react with solution is the equivalent of a single plate distillation operation while the chromatographic or ion-exchange column is a multiple-plate method—the multiplicity of the plates being represented by the reciprocal of the rate of flow of solution through the column. It seemed to us that the chromatographic method had such

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advantages from the standpoint of kinetics as to justify its adoption.

Experimental

The mineral was prepared from a stock of sphalerite from the Tri-State District supplied by the Eagle-Picher Mining Co. The mineral was crushed, ground, sized, and purified by treating with hydrogen peroxide. The latter step seems to remove organic coatings that might be present and leaves the mineral in the nonfloating condition that we expect the pure mineral to display. The washed, sized, and deslimed mineral was stored in glass vessels and formed into ion-exchange columns immediately before use. Fig. 1 shows the general experimental setup. The columns consisted of 12 to 15 g of mineral in a length of about 10 cm and a cross-section of somewhat less than 1 cm. Since the particles used were in the size range of approximately 48 to 325 mesh, a large number were present in any cross-section so that the behavior of the column was substantially the behavior expectable in any tank of commercial size. That is, the wall effect, if any, was of minor importance.

In using the column, one problem was the development of a method of feeding solution so that the rate of flow would be constant. This was obtained by use of a relatively high head and by inserting a mechanical resistance (clamp) in series to that offered to the passage of solution by the mineral column. During a test, the flow rate was checked repeatedly and adjustment was made by variation in the setting of the clamp.

The radioactive tracer was received from Oak Ridge and kept in the usual fashion and with proper precautions. Blending of the active silver with ordinary silver nitrate was made to suit the needs of the various experiments, and the combined solution was fed from a constant-head storage tank.

An idea of the silver content of the effluent solution was obtained by passing effluent solution

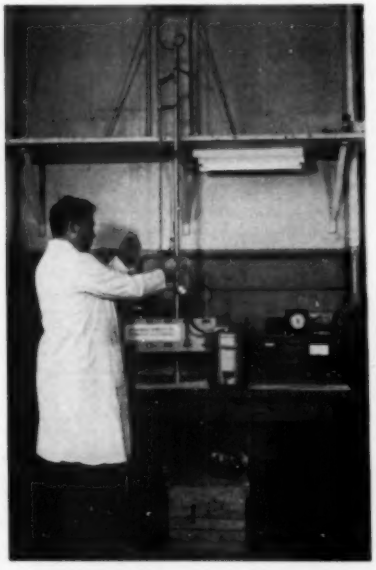

Fig. 1—General experimental setup.

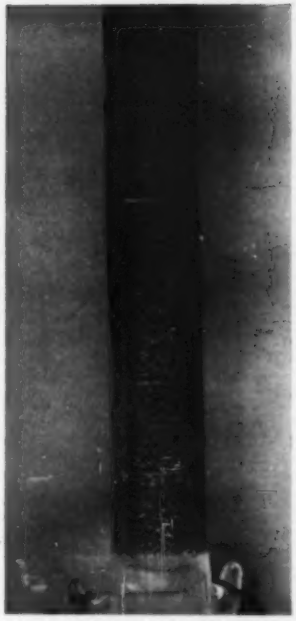

Fig. 2—Packed sphalerite bed showing discoloration progressing downward.

through a concentric-shelled flow counter similar to that developed by Barnes and Salley for the evaluation of potassium.[9] Prior use of a flow counter copied from the design of Kettelle and Boyd[10] was not particularly successful because that form of counter cannot be cleaned readily of silver ions that become absorbed on the walls of the plastic container.

In addition, samples of the effluent were taken every few minutes for analysis. A standard volume of each sample was dried on a planchet and counted, using a standard end-window counter. After deduction of the background, use of the appropriate factor gave the silver analysis. The factor was such as to allow for the time-decay of silver 110, for the dilution of active silver with barren silver, for the position of the planchet below the window counter, and for the volume of solution taken for analysis. All these matters are now standard in the field of radio chemistry as may be noted by reference to one of the texts in that field.

In general, the indications given by the flow counter were at least quantitatively correct. Certainly the flow counter would indicate the incipience of break-through but the flow counter would not give accurate analyses after it had begun to absorb silver from the solution.

Results

Aside from preliminary experiments in which the flow rate and mineral volume were varied, the experiments were all made at a flow rate of about 10.8 ml per min. Since the amount of mineral in the columns was of the order of 12 to 15 g (volume 3 to 4 cc) and since the volume of voids is of the order of 3 ml, it appears that the retention time of the silver-bearing solution in contact with mineral was of the order of 15 to 20 sec.

Under these conditions when the concentration of

the influent solution was very low (10^{-4} mols per liter), all of the silver was removed by the sphalerite. This experiment was continued for 27 hr, and there was no trace of silver in the effluent to the very end of the test. The feed solution, in this instance, contained a relatively high proportion of radiosilver so that a concentration of silver in the effluent of 10^{-9} mols per liter would have been detected readily.

This experiment shows that in spite of the short period of contact between a given volume of solution and the mineral column, all of the silver ions have an opportunity to reach the sphalerite, and that all of them take advantage of it.

If higher concentrations of silver are used in the influent solution, the abstraction is again complete at the beginning of the test. After a measurable length of time, the effluent solution begins to carry silver. This shows that although the same opportunity exists for the silver ion to reach the sphalerite, silver ion fails to stick after the mineral has acquired a sufficiently dense coat of silver. Of course, zinc ion was given up for the silver adsorbed. This was determined colorimetrically through the use of dithizone as indicator.[11]

The reaction with silver ion discolored the sphalerite which turned darker, see Fig. 2. In some experiments, in fact, the mineral became quite black. The initial material was the honey-colored mineral from the Tri-State District, which has been the common laboratory material in flotation experiments with sphalerite.

The course of the experiments is typified by Fig. 3, which shows the silver uptake as a function of the silver throughput. The figure consists of two parts. The upper part shows the instantaneous uptake and the lower part the cumulative uptake. The three curves for slightly different pH values (from 5.4 to 6.4) overlap almost exactly in the instantaneous curve, yet differ slightly in the cumulative chart. This is because the ordinate in the upper chart disregards the weight of mineral in the column while the ordinate of the lower chart allows for it. Fig. 3 shows that up to the break-through time denoted by point A, the amount of silver abstracted from the solution by the mineral is proportional to time; this amount, of course, being the entire quantity of silver coming to the column with the influent solution. Past the break-through point, the mineral is still removing silver from solution, but it fails to remove all of it. During the second period, the removal of silver is at a decreasing rate, as the coating of silver thickens.

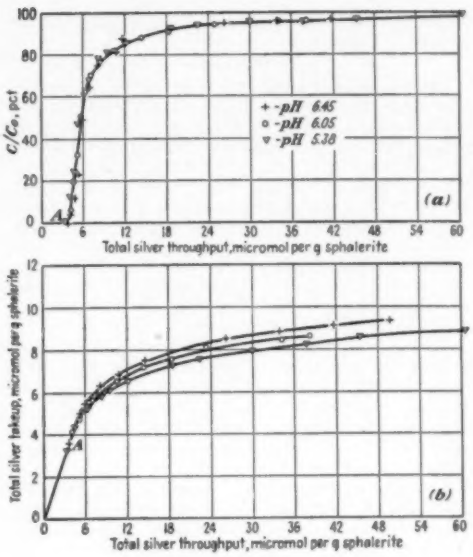

Fig. 3—Concentration histories showing effect of varying pH.

Clearly we are faced with the likelihood that two reactions are involved. The first seems to go to completion within the time allotted by our experimental procedure; it is our opinion that providing diffusion of silver ions within the percolating liquor can take place sufficiently to bring every silver ion to the surface, an opportunity for completion of the first reaction will have been given. The second reaction does not appear to depend on any factor arising within the aqueous solution.

Further evidence of the existence of this second phenomenon was obtained quite fortuitously during one of the experiments. The experiment involved the use of a rather dilute influent solution so that when the day was over, the experiment had not been completed. The flow of solution was stopped overnight and was resumed the next day without disturbing the column. When the flow was interrupted, the column was still abstracting some silver but not all of it. On the next day, the mineral was found to be much more avid for silver, hungry

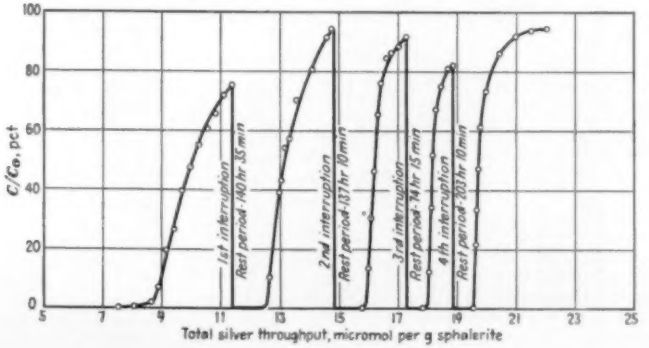

Fig. 4—Concentration history showing effect of interruptions.

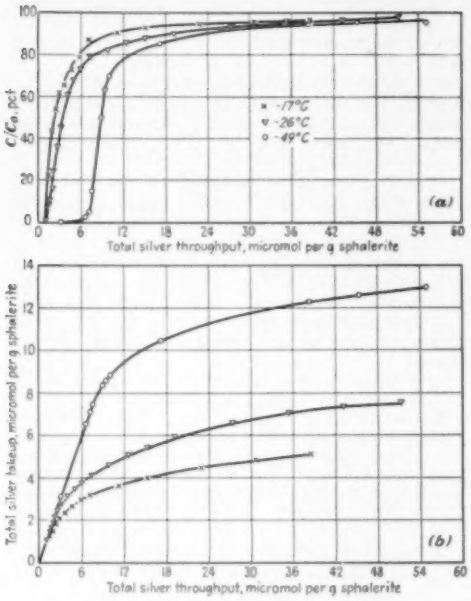

Fig. 5—Concentration histories showing effect of varying temperature.

enough, in fact, for it to completely deplete the influent solution. This was so intriguing that the main purpose of the experiment was changed. The flow of solution was continued throughout the remainder of the week with nightly interruptions. Apparently here was an instance where in a sense the mineral got tired of picking up silver in the usual course of ion exchange but where the activity of the mineral was restored by rest.

The interpretation of this phenomenon is that there is a diffusional rearrangement within the solid going on all the time. During the flow of solution, the rate at which this rearrangement occurs is so slow that few new loci are provided for the adsorption of silver. But when the mineral is at rest, the rearrangement is sufficiently extensive to provide considerable adsorption capacity—in fact enough to entirely deplete the liquor in the time of its passage through the column. The system behaved in the same way at each cycle. The experiment was again repeated with longer interruptions, as may be seen in Fig. 4.

On wholly speculative ground, it may be supposed that the silver ions and perhaps the zinc ions also diffuse so as to form localized polymolecular crusts alternating with barren spots. Such an effect could occur if proper values are assumed by the various interfacial energies.

On the other hand, it may be assumed instead that the silver ion diffuses into the zinc sulphide lattice. The authors do not favor this alternative because it has been shown that both sulphur and zinc ions are not prone to diffuse in sphalerite,[12] but this alternative cannot be ruled out.

If either solid-diffusion hypothesis is correct, temperature may be expected to play a large part in the control of the second reaction, i.e., the slow reaction. That this is the case may be seen from Fig. 5, which presents the results obtained at different temperatures: at a high temperature, the slow reaction is much more rapid than at a low temperature. This suggests that at the temperature of boiling water the break in the cumulative curves may not be noticeable, while in freezing water, the slow reaction may be markedly slower.

Within a limited range pH does not play a major role in the action of silver ion on sphalerite, see Fig. 3.

Solutions that differ markedly in silver ion concentration, also, behave in much the same way. However, as a much greater volume of a dilute solution is required to carry the same amount of silver as a concentrated solution, the use of dilute solutions provides more opportunity and time for diffusional rearrangement. Fig. 6 shows that the rate of uptake at the end of each experiment corresponds to the formation of surfaces that still have some avidity for silver. The overall uptake is distinctly a function of the concentration, being more in the case of the more dilute solutions, as may be expected on kinetic grounds from the general character of slow-diffusional phenomena.

To provide the beginning of a comparison with the usual sphalerite activator, one experiment was made in which radioactive copper was substituted for radioactive silver. Also, another experiment was made with silver ion and copper-preactivated sphalerite. The results obtained are given in Fig. 7. It will be seen that in the copper-exchanging experiment there was a build-up in the adsorbed copper. In this case, however, the mineral took up a maximal amount of copper with no slow reaction to supplement the formation of the primary coat. In other words, copper behaves like silver at low temperatures, only more so.

Interpretation of the experiment on the copper-preactivated silver-exchanging experiment is not

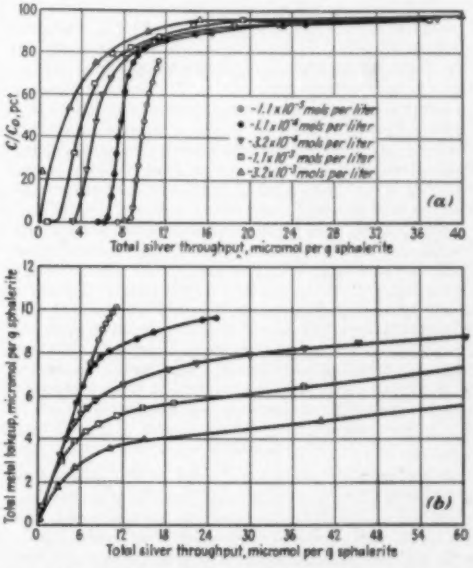
C/Co, pct
○ -1.1 x 10⁻⁵ mols per liter
● -1.1 x 10⁻⁴ mols per liter
▽ -3.2 x 10⁻⁴ mols per liter
□ -1.1 x 10⁻³ mols per liter
△ -3.2 x 10⁻³ mols per liter
(a)
Total silver throughput, micromol per g sphalerite
Total metal takeup, micromol per g sphalerite
(b)
Total silver throughput, micromol per g sphalerite

Fig. 6—Concentration histories showing effect of varying solution concentrations.

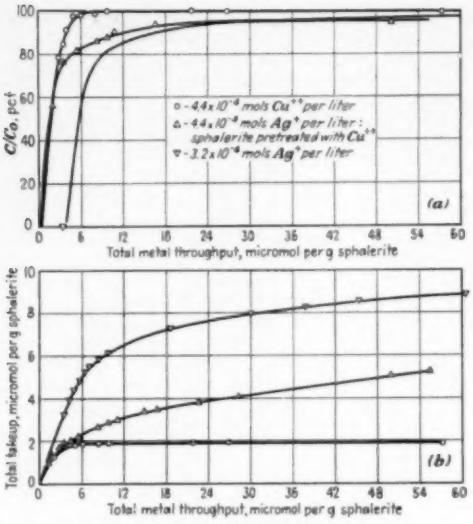
C/Co, pct
o - 4.4 x 10⁻⁴ mols Cu⁺⁺ per liter
Δ - 4.4 x 10⁻⁴ mols Ag⁺ per liter; sphalerite pretreated with Cu⁺⁺
▽ - 3.2 x 10⁻⁴ mols Ag⁺ per liter
(a)
Total metal throughput, micromol per g sphalerite
Total takeup, micromol per g sphalerite
(b)
Total metal throughput, micromol per g sphalerite

Fig. 7—Concentration histories showing comparison of copper with silver tests.

completely possible as it is not known whether Ag^+ exchanged for Cu^{++} or for Zn^{++}. Since the total Ag^+ uptake exceeds the total Cu^{++} uptake in the other experiment, and also on the chemical grounds, the Ag^+ is more likely to have exchanged with Zn^{++}. Tracer experiments in this direction should be profitable.

The amount of copper picked up by sphalerite in the copper-exchanging experiment is not nearly as much as the amount of silver that can be picked up. Furthermore, a ceiling appears to exist.

Fig. 7b shows that the mineral will adsorb up to 1.89 micromols of copper per gram of mineral. On the basis of preliminary surface measurements by the gas adsorption method,[13-15] this uptake appears to come close to a complete, closely packed monolayer of copper ions. It seems, therefore, as if a determination of copper-ion adsorption may perm. evaluation of the amount of surface on sphalerite. Further work is needed in this field before a conclusion is accepted.

It is obvious that further experiments with copper would be profitable and that similar experiments might be conducted with a number of other metals replacing zinc at the surface of sphalerite. Still another possibility involves a study of the joint action of metallic ions like silver and copper. It is entirely possible that one of these elements acts as a catalyst to facilitate the formation of a coating by the other. Such phenomena may be important in ore genesis as well as in ore-treatment processes.

Summary

A preliminary study was made of the adsorption of silver ion by granular sphalerite. The mineral was arranged as an ion-exchanging column, and the dilute influent electrolyte was marked with radioactive silver. At suitably low flow rates the solution is completely stripped of silver until the coating becomes substantial. The rapid ion exchange that occurs during flow of solution through the column is supplemented by a second or slow reaction which appears to be controlled by diffusion in the solid state.

In a single experiment with copper instead of silver at room temperature, no slow or solid-diffusion reaction was observed. Much additional work remains to be done.

Acknowledgments

This study was made possible under a contract between the Division of Industrial Cooperation of the Massachusetts Institute of Technology and the U. S. Atomic Energy Commission. We wish to record our appreciation of this opportunity to work on this problem and to express our thanks to W. E. Kelley, V. L. Parsegian and R. F. Van Wye, of the New York office of the Commission, for their interest and assistance.

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A Graphic Statistical History of the Joplin or Tri-State Lead-Zinc District

by John S. Brown

IN 1925 the writer undertook a detailed statistical study of all producing areas in the Joplin district as a basis for evaluating programs and measuring objectives. For this purpose, the published figures in the yearly volumes of Mineral Resources were used, supplemented for earlier years by publications of the Missouri Geological Survey and other local and less official sources. When all else failed, the available data were projected backward to hazard a reasonable guess as to the unrecorded early output of important areas. Fortunately, the proportion of such prehistory production is not a large factor in any of the totals. These results were used during the next few years to measure the relative importance of various producing areas and to predict the peak period of development of the all-important Picher field. For the purpose of this review, the charts have been completed to the end of 1950. During World War II, the U. S. Bureau of Mines became interested in a similar study and issued comprehensive statistical tabulations of data up to 1945 (Info. Circular 7383), which have been checked against the figures used herein. This tabulation, however, does not include all the earlier data used by the writer nor does it offer any estimates of the wholly unrecorded era in the beginnings of the earlier camps.

The area covered in this study is shown in Fig. 1 on which are indicated the relative location and approximate outlines of the principal producing camps. This also shows the approximate yield to date of each major camp in terms of combined lead and zinc concentrates. The output of zinc concentrates is roughly seven times that of lead. Hence, the economy of the district has depended primarily on the price of zinc, with lead as an important byproduct. Over much of the productive period, lead concentrates averaged about twice the value of zinc concentrates per ton, and in certain mines or areas the proportion of lead to zinc was substantially above average.

The Joplin district is largely flat prairie but is partly moderately dissected, partially wooded land with a relief generally less than 100 ft. The rocks are almost flat-lying, nearly parallel to the surface, and the chief ore formation is the Mississippian Boone limestone, including its cherty phases. This formation either outcrops in the producing areas or is covered by a thin veneer of Pennsylvanian shales. Virtually all the ore occurs within 400 ft of the surface, and a large part at less than 300 ft in depth. Most of the land was divided into small farms or town lots before mineral development; tracts seldom exceeded 160 acres, and averaged considerably less. Mineral rights followed the surface ownership, segregation was rare, and a system of leasing for mineral development became well established early in the region's history, many landowners deriving small to sizable fortunes from royalties. Because of the shallowness of the ore and other factors, prospecting and mining was cheaper than in almost any comparable mining district in the United States. This situation, coupled with the widely divided land ownership, offered a fertile field for promoters and speculators and led to the rise of many small mining concerns. Only in its later history, under stern economic compulsion, has control tended to centralize in a few companies.

Under these conditions, any important new discovery or successful development had much the effect of a gold rush or an oil boom. Every property in the area was leased quickly, promptly drilled, and, if ore was found, it was soon on the market. Many companies and individuals participated, and the average producing lease-hold probably was about 40 acres in extent. Any important field thus was attacked by anywhere from 10 to 100 or more producers. Production zoomed, eventually steadied or wavered, and ultimately subsided, leaving a desolation of tailings mountains, cave-ins, empty housing, and wreckage. The object of this paper is to depict the pattern of this process, so far as metal production is concerned, and to note the way in which it reacted to economic and political pressures.

Production Charts

In Fig. 2 is charted the production record, in tons of lead and zinc concentrates combined, of eight of the principal camps, which together account for approximately 99 pct of the total district production, over the years from 1870 to 1950. This period covers all but the very minor beginning of mining history. Two important camps are divided by state lines; hence, it has been necessary to combine production records for the two portions, based on estimates that may be slightly in error. Certain camps are subdividable into important units for which separate figures are available in whole or in part and have been charted as fractions of the major unit. The corresponding price of zinc is shown above all the charts.

Three camps, Aurora, Neck City, and Galena, show a remarkably symmetrical graphic pattern, which is interpreted as the norm. The curves rise steeply to a peak, level off for an irregular interval, and then drop sharply to zero on a slope corresponding roughly to that covered by the initial rise. The three portions of these charts seem appropriately characterized by the designations of youth, maturity, and decline. On the whole, with some irregularities, the production in each of the three periods seems to be almost equal.

A fourth camp, Granby, fails to conform to the normal pattern. It exhibits a very long period of reasonably uniform, stabilized production corresponding to maturity, followed by a rather precipitate decline. Its youth is hidden in the era of prehistory. This habit of steady, long-continued production at an even keel is attributable to the fact that this camp, more than any other, was controlled largely by a single principal owner at any given period over most of its history and this permitted the imposition

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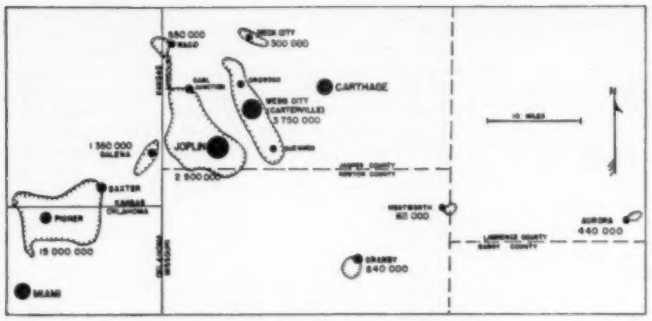

Fig. 1—Index map of Joplin district.

of a much more orderly plan of development and production. Oronogo, a subdivision of Webb City, shows a rather similar curve for much the same underlying reason. No doubt this pattern was much more satisfactory for the operating companies, probably was better for the communities, and likely resulted in the recovery of a greater percentage of the metallic wealth.

The greatest of all the camps, the Picher district, first began operations in its most southerly corner about 1908. It has since produced considerably more than all the other camps combined and shows the next most regular pattern. Failure to appreciate the significance of the new camp, coupled with a serious water problem, caused it to develop slowly for a few years. However, its importance became apparent about 1915, and it rapidly ran the normal cycle, reaching the peak of youth and entering maturity in 1926. The mature stage was interrupted from 1930 to 1935 by the Depression, although a substantial production was maintained even in the hardest year of this adverse period. Maturity apparently terminated in 1941 (or possibly 1937) and the field is now well down the path of decline. The chief abnormality of this curve was caused by the Depression. The total yield in maturity was moderately greater than that of youth, and the period of decline, which now shows one third to one half the yield of maturity or youth, would appear to be about half completed.

A somewhat similar but more abnormal history is that of the Waco camp. Youth, 1916 to 1923, had the usual steep rise. Maturity ran into the Depression, which brought complete cessation of production in 1932, with an irregular resumption in the late thirties and the ensuing decade. No normal segregation of maturity and decline seems feasible, but the end of both appears to be now at hand. The yield of the combined periods of maturity and decline totals almost exactly twice that of youth.

There remain two important and unusually complicated situations represented by the Joplin and Webb City fields in Missouri. These together, and roughly in equal proportion, were the mainstay of production in the period from 1900 to 1918, supplying more than two thirds of the output of the district, each field achieving its cycle of maturity in this era. Suddenly, in 1917, production in both fields began declining and practically reached zero in 1920. This extraordinary behavior was the direct result of the sudden development of the much larger and richer Picher field. When the magnitude of this new discovery became apparent, there was a veritable stampede in which drills, mills, and personnel were moved to the new field. The problem of keeping the old fields dewatered under diminished output became insupportable, and the mines were abandoned and the workings flooded. In spite of the abandonment of these major camps, however, production from the new field flooded the market, and the American Zinc Institute was formed to promote new uses for the excess zinc.

The ready availability of so much equipment, manpower, and organization, transferrable from the old camps to the new, doubtless steepened the curve of development in the youth of the Picher field, and in 8 years, from 1918 to 1925 inclusive, the inevitable peak of youth was attained. For a field of equal size in a wholly new or more remote area this growth likely would have taken more than twice the time. On a minor scale, a similar history characterized the Waco field.

The brief postwar depression of 1921 caused a slight hesitation in the youthful progress of Picher and Waco. The depression of the thirties, however, put Waco out of business completely and, but for the presence of a few stronger and better integrated companies which had now developed, might well have done the same for Picher.

The Price Factor

Thus far one factor in these charts has been ignored, which often has been considered the prime influence on production. This is the element of price. So far as these individual camps are concerned, the graphs seem to indicate clearly that relative age and productive capacity, which is closely related to grade of ore, are far more important factors than price, the effect of which is too greatly modified by being spread over the entire industry. Picher and Waco achieved the first half of youth at a prodigiously steep rate in the face of prices that were declining drastically. Aurora completed the latter half of youth on a declining price. Galena, Granby, Joplin and Webb City show moderate fluctuations in youth, which probably reflect vaguely the price fluctuations of the 90's, without, however, seriously modifying their general upward trend. In only one of the eight major camps, namely Picher, is the peak of youth coincident with that of a sustained price rise, which occurred in the latter half of youth, and here the peak of production is out of all proportion to the moderate increase in price.

The end of maturity probably is somewhat more affected by price fluctuations and economic stresses. For Aurora and Galena, it seems to be related fairly closely to the peak of a sustained price rise. Neck City and Joplin ended maturity almost coincidently with the long and gradual rise of prices prior to World War I, and the ensuing war boom failed to

modify the subsequent downward trend, although, for Joplin, it nearly succeeded in extending the mature stage. Webb City, and perhaps Granby, developed abnormal peaks marking the apparent end of maturity with only a slight delay in relation to the fantastic price rise of World War I. Waco was too much affected by the Depression for a clear interpretation. Picher ended maturity about in the middle of a long-extended rise in prices related to World War II, and neither premium prices during the war nor inflated markets thereafter served to modify its downward trend.

Both maturity and decline show moderate correlation between volume of production and swings in the price level, and the several periods of decline probably would be tied closely to this factor if it were not for more violent external effects, such as wars, depressions, and the discovery of the Picher field. Three camps, Aurora, Neck City, and Galena, were closed by the price deflation following World War I, but, since this happened also to coincide with the great expansion of Picher, the cases are not clear-cut. Joplin and Webb City had their periods of decline amputated at the beginning by the same fate, and Granby was in much the same situation. The decline of Picher and Waco undoubtedly has been retarded in the past 5 years by the current price inflation.

The Grade Factor

A factor equally or more important than the price of metal, apparently, is the grade of ore available for production, although, unfortunately, the published statistics of grade are not complete enough for thorough analyses of the relations. Mineral Resources and the succeeding Minerals Yearbook give the percentage content in zinc and lead under the headings of the three areas, Southwestern Missouri, Kansas, and Oklahoma, from 1909 to the present. For Oklahoma, this grade may be assumed to be synonymous with that for the Oklahoma portion of the Picher field and for Kansas the contribution of Waco, Galena, etc. was so small (approximately 8 pct on the average) that the Kansas grade may be used to represent the Kansas side of the Picher field without serious error. On that basis the two have been combined in proportion to their respective tonnages to represent the grade of the Picher field, shown on the graph of production. It will be seen that the camp began operating on ore averaging about 5 pct combined zinc and lead (metallic content) and has declined unevenly but fairly consistently to a yield of exactly half, 2½ pct. (In all these grade figures the grade used is for crude ore ignoring that of remilled tailings. Concentrate production, however, includes tailings production).

The beginnings of the Missouri field are uncertain as to grade of ore prior to 1909 and thereafter are doubly complicated by the existence of numerous separate camps yielding a considerable variety of ores. In the two major camps, Joplin and Webb City, two distinct classes of ore were mined, "soft ground" and "sheet ground," respectively, the former more pockety and richer, the latter more uniform in occurrence but of lower grade. Grade and tonnage for the two classes were listed separately from 1909 to 1920, but they are combined here into a single grade weighted for the respective tonnages to give the grade line on the Joplin and Webb City production chart, Fig. 3. This shows that the average ore mined in 1910 contained 2 pct combined zinc and lead and the grade declined at a rate that would have reached 1½ pct in 20 years had not production ceased in 1920. Projecting this line backward, we may infer that the average grade of all ore mined prior to 1910 must have been between 2½ and 3 pct metal content, and in the early years of richer camps probably reached 4 to 5 pct. At the time Picher became important, however, the available grade of ore in the new field was substantially more than twice that then available on a tonnage basis in Missouri. Naturally, only a rich mine with a reasonable water situation could survive outside the Picher field.

With the closing of Joplin and Webb City in 1920, the only important remaining production in Missouri was that of the Missouri side of the new soft-ground Waco camp. The Missouri grade figures from 1920 on are plotted on the Waco production chart. In the important decade from 1920 to 1930 they probably represent rather accurately the actual grade of the Waco field, even including its Kansas portion. Thereafter, the grade is influenced appreciably by revivals of Joplin, Webb City, etc. but still probably is not too far from the true Waco line. The initial grade at Waco seems to have averaged about 3½ pct falling to a present and final level around 2 pct.

If production and price fail to show any close interrelationship, the same is by no means true of price and grade. Compare the Picher grade curve with the price line and, except for the long-range downward trend of the grade line, all fluctuations in the two are virtually mirror reflections of each other; when the price went up, the grade of ore mined dropped and vice versa. The same is true of the Missouri curves. This is merely the operators' means of adjusting the fluctuations in value of his selling product (concentrates) to meet the relatively more stable elements of cost and leave an operating margin. When concentrates yield less money, he mines his richer ore to obtain more concentrates per ton of ore at a reduced cost; when metal prices rise, he mines the lower grade ore, which formerly failed to yield a profit. This procedure is satisfactory within its limitations but cannot alter the downward trend of the grade line over the life cycle of a district or camp.

The question may be raised as to whether or not the declining grade curve may represent largely technological progress—the lowering of costs and improvement of methods to make ore of what formerly was waste, and whether or not this process might not continue almost indefinitely. In the author's opinion, there is a small fraction of truth in this idea. There is, of course, some low grade marginal ore in this district. But in the case of all soft-ground camps, including Picher, which is more closely allied to the soft-ground deposits than to the sheet ground, it is believed to be less in total volume than the original ore mined and far less in potential yield of concentrates. In the Webb City and Joplin camps, where sheet ground, a low grade form of mineralization widely distributed in rather gradational habit, was an important contributor to the output, the idea has some validity but probably is exaggerated easily.

Probable Reserves

If the foregoing review and analysis have any value other than historical it should be in: 1—assisting in the evaluation of any new camps that may be discovered, and 2—aiding in a forecast of the possible remaining potential of existing camps. Only the second item will be discussed here.

First, it seems clear that the greatest potential in the district still is that represented by the declining phase of the Picher field. Youth yielded something over 5 million tons, and maturity, as charted, over 7 million tons of concentrates. The peak year (1925) was almost equalled by the succeeding year (1926), and if the latter were used as the dividing line, the two periods would be almost equal at a little over 6 million tons each. Accepting this interpretation as a tentative yardstick, 6 million tons may be expected on the decline, of which 2,244,000 have been produced, leaving 3,756,000 expectable. Considering the recent difficulties of maintaining current output, even with insistently rising prices, this forecast seems optimistic. A second look suggests that the end of maturity could have been in 1937 (the Kansas side shows this clearly) except for the strong armament boom of 1940-41. Cutting maturity back to 1937 would reduce the production in that period to 5,680,000 tons, nearly equal to that of youth (1925 basis) and would augment decline to 3,986,000 tons, leaving a probable potential of about 1,750,000 tons of concentrates. The writer believes that the final production may be nearer the latter figure than the former, especially considering that declining fields are particularly vulnerable to stress and strain and that, once the heavy pumping cost for the field becomes unsupportable, production is likely to cease abruptly, unless artificially supported.

The indicated grade of ore to produce these concentrates, on the basis of the smaller yield, would be about 2¼ pct combined metal content, or about 80 million tons of crude ore, producible in 12 to 15 years. The larger figure (3,750,000 tons concentrates) would imply a life of 40 to 50 years with small yearly output in the latter half of the period, an average grade less than 2 pct, and a total tonnage of 175 million. This compares with a total crude ore output to date of a little over 400 million tons from this camp.

It is clear, likewise, that the Webb City and Joplin fields must have a substantial reserve of ore, *which would have been produced had not Picher been discovered.* (Whether or not this ore is still producible from this reserve is another matter). For Webb City, the charts show a production of a little over 2 million tons of concentrates in youth, a little over 1 million in maturity, and nearly 600,000 in the decline, including in this the revival of 1935 to 1950, which has netted 300,000 tons. Averaging youth and maturity at approximately 1,620,000 each, and assuming decline to have equal value, it would seem that 1 million tons of concentrates may remain in this field. *The grade of ore to yield this, however, will not much exceed 1½ pct at the start, and would almost certainly drop to 1 pct or below at the end.* A million tons from 1¼ pct ore, or 80,000,000 rock tons is indeed a challenge to the champions of improved methods and lowered costs. They may retort that this is but little lower than the grade mined in the era prior to 1915. As discussed later, however, that was another era.

The Joplin camp, with 1 million tons of production in youth, 1 million in maturity, and ½ million in decline, suggests the probability of exactly 50 pct of the potential of Webb City; ½ million tons of concentrates from 40 million tons of rock at 1¼ pct grade.

The remaining camps seem to offer only small possibilities for additional production. However, a careful appraisal of Neck City might be rewarding. The period of decline for this camp, although superficially normal, was short and steep, the yield less than 50 pct that of youth, less than 33 pct of maturity. A plausible explanation for the rapid decline would seem to be that the rush to Picher and Waco caused its abandonment before its exhaustion. Perhaps 50,000 to 75,000 tons of concentrates exist here, and the grade of the crude ore may be a bit above that of Webb City and Joplin. However, the water problem is sizable.

It may be noted that World War II stimulated great efforts in the Tri-State district to maintain or expand production, both on the part of private operators and governmental agencies. The premium price plan was devised probably more with a view to increasing production in this area than for any other single objective. Under it there was substantial exploration; numerous camps were re-examined, prospected and revived, the results, in the main, are shown in Fig. 2. Moderate production was obtained from several dormant camps and moderate increases from others. As a commentary on this program, there is inserted the historical chart of Wentworth, a minor camp but the only one which yielded, under this program, any large production in comparison to its past history, in this case some 30,000 tons of concentrates, approximately equal to its past production. The future of the Joplin district seems to be, if anywhere, in an extensive long-range program of searching for new major camps or entirely new producing horizons in the existing camps, with no guarantee of success.

The Price-Grade Multiple

The implications of the price-grade relation seem so significant as to deserve special consideration, particularly with reference to the matter of possible reserves. If one reacts inversely to the other, it is obvious that by multiplying them something resembling a constant may be obtained, and this might be a useful figure in estimating the price necessary to yield production at a given, and lowered, grade of ore. This idea is illustrated in Fig. 3, which gives the price of zinc from 1900 to 1950, in comparison with the grade of ore from the Missouri fields on one hand and Picher on the other. It also charts the multiple of price for these two areas.

The resultants are by no means smooth curves but they are considerably less erratic than either price or grade. Noting first the Missouri price-grade curve, it plainly shows a division into two eras, one prior to 1915, for which grade figures are available only to 1909, but which, it may be inferred from general knowledge as to grade and by an inspection of the price chart, would undoubtedly hold good back for many years, probably to 1880, or 35 years. This was the era when mine wages ranged from perhaps as low as $1 to a maximum of about $2.50 per day, with no social security, no unemployment insurance, little health or safety provision, and low taxes. In that era the price of zinc averaged about 5¢ per lb with only mild fluctuations compared to the succeeding period and the price-grade multiple ranged between 10 and 15, averaging a little less than 12 in the later years.

The inflation of World War I ushered in a new era which has likewise run 35 years to the present day. The price of zinc, although fluctuating more widely, has averaged about 8¢ per lb for these 35 years, an inflation of 60 pct. Coincident with this inflation came the rise of the Picher field with its richer ore, and the average grade of ore mined in the district as a whole approximately doubled. Inevitably, as a

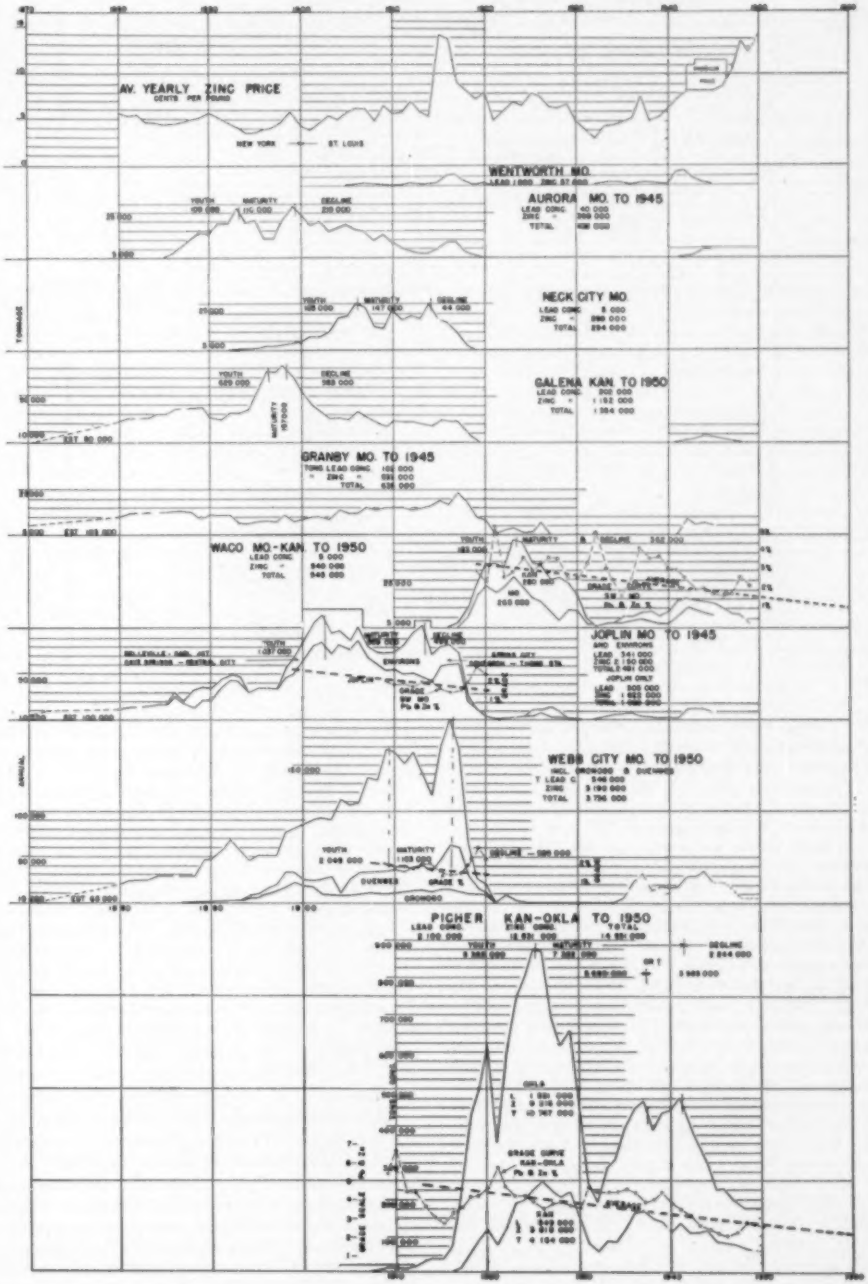

Fig. 2—Production record of the principal mining camps in the Joplin district.

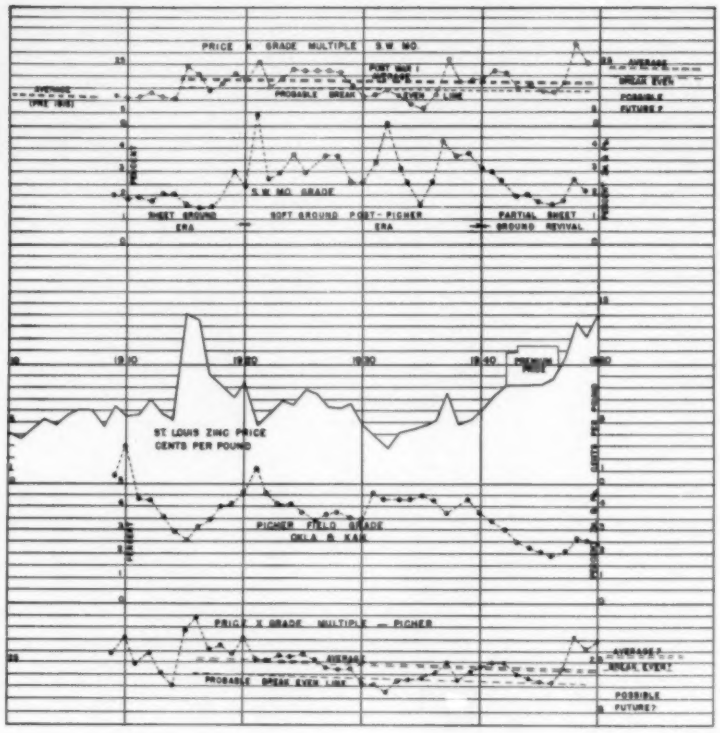

Fig. 3—Price-grade relationships in the Tri-State district.

result of these two controlling elements, the price-grade multiple rose to a higher average level, practically double that of the former era. For the Picher field, it is approximately 25; for Missouri, after 1915, about 18. In all cases, there is a slight declining tendency from the beginning to the end of an era, perhaps explainable as caused by technological improvement in part (lowering of costs and improvement of processes to permit mining lower grade ore) and perhaps in part to the liquidation of the capital charges (for Picher) permitting operation at lower cost and holding down prices to some slight extent.

Prediction is hazardous, but the suggestion seems warranted that the sharp and insistent rise of the graphs for the multiple in the past 3 years (1947-50) presages the beginning of a third era, perhaps another 35 years, more or less. The writer suspects that the price-grade multiple is leaping to a new level and will never return to its former position.

Assuming that the multiple, which now stands at 35 for the Picher field, may average 30 over the next decade, then the requisite for mining 2 pct ore is a 15¢ zinc price; for a 1½ pct ore, 20¢. This is not to imply that production would cease below 15¢, for the probable break-even line is somewhat lower, and dips below the 15¢ price could be weathered for moderate periods.

In the Missouri field, where it appears the average of the multiple may rise to only 25 on a basis corresponding to Picher, the requirement for mining 1½ pct ore would be about 17¢ zinc and for 1 pct ore a price of 25¢ is indicated. Since the Tri-State area, owing to its decline in output with a corresponding increase from other sources, has lost completely its power to dominate the market, it seems obvious that the price will be dictated mainly by outside influences. Whereas it would seem quite reasonable for the price to meet the requirements of production from the Picher field for a substantial period, it also seems unlikely that it will fulfill the requirements for the lower grade portion of the Missouri fields (the 1 to 1¼ pct ore). This issue is likely to be decided largely on a political basis. In doing so, however, the question of manpower may deserve careful scruitny. It is likely that any production from the lower grade portion of the Missouri reserve will require manpower per unit of product greatly in excess of that necessary in other areas. This might be a serious objection in some situations, and less in others.

Conclusion

The method of analysis offered here appears to have definite uses and limitations. It probably can not be applied at all, or only with drastic modifications, to simple veins or steeply dipping deposits where the area open to attack is limited in comparison with the extent of the deposits. It might fit well the situation of placer camps, residual deposits, and shallow zones of secondary enrichment. It should have considerable application to other deposits of the Mississippi Valley type, but each case doubtless will involve its own peculiar problems of adaptation to local geological, economic and historical influences.

Flotation Rates and Flotation Efficiency

by Nathaniel Arbiter

THE separation of minerals by flotation can be regarded as a rate process, with the extraction of any one mineral determined by its flotation rate, and the grade of concentrate by the relative rates for all the minerals. So regarded, the significant variables for the process are those that control the rates. These variables are of two types, the first describing the ore and its physical and chemical treatment prior to flotation and the second characterizing the separation process in the cells.

This paper will examine the variation in rates for a group of separations, will show that a simple rate law appears to govern, and will consider the relation of the control variables to the rates. The use of rate constants for evaluation of performance and efficiency will be discussed.

Flotation involves the selective levitation of mineral and its transfer from cell to launder. The flotation rate is the rate of this transfer. It may be defined by the slope of a recovery-time curve for any cell in a bank, or at any time in batch operation. The objective in flotation rate study is an equation expressing the rate in terms of some measurable property of the pulp. This can be either the concentration of floatable mineral in weight per unit volume[1, 2] or a relative concentration, which will be a function of the recovery.[3] A rate equation for an actual flotation pulp will contain at least two constants, both to be determined from the data. One of these, the initial concentration or proportion of floatable mineral, is not necessarily equal to the feed assay because of nonfloatable oversize or locked particles.[4] The other, a rate constant, is a measure of proportionality between the rate and the pulp property on which the rate depends. The value of the rate constant will be determined by the values of all variables which control the process and will be changed by significant changes in any of them. It is, therefore, a direct measure of performance. Where recovery or grade change continuously with flotation time, the rate constant will be independent of time and will characterize the entire course of the separation.

Development of Rate Equations

Rate equations can be developed either by analysis of the mechanism of the process or by direct fitting of equations to recovery-time data. Sutherland's attempt by the first method[1] suggests that the effect of particle size variation on the rate complicates the derivation of a simple equation applicable to an ore pulp. A further problem with an ore is the concentrate grade requirement, which usually involves a variable rate of froth removal. Thus the final rate for any cell may depend on the froth character and froth height, as well as on the pulp composition. This does not imply that each cell cannot reach a steady state[5] in which the rate will depend ultimately on pulp composition.

The second method is the fitting of rate equations consistent with the necessary boundary conditions* to experimental recovery-time curves. On the assumption that under constant operating conditions the flotation rate is proportional to the actual or relative concentration of floatable mineral in the pulp, a generalized rate equation may be expressed as follows:

$$\text{Rate} = Kc^n \qquad [1]$$

where K is the rate constant, c is some measure of the quantity of floatable mineral in the pulp at time t, and n is a positive number. In previous rate studies, the value of n has been taken as 1, either by direct assumption,[6] or as a result of the hypothesis that bubble-particle collision is rate determining.[1] A first order equation results, which after integration in terms of cumulative recovery R, leads to

$$\text{Log}_e \frac{A}{A-R} = Kt \qquad [2]$$

The quantity A is the maximum possible recovery with prolonged time under the conditions used. No conclusive proof for the validity of this equation in flotation has been advanced. The evidence cited in its support consists entirely in the demonstration that it appears to apply to a limited number of recovery-time curves.[6-8] It will be shown subsequently that this procedure is not sufficient to establish the order of a flotation rate equation. The possibility that the equation may be of higher order therefore requires examination.

If, in particular, the exponent in eq 1 is assumed to be 2, then after integration there results

$$R = \frac{A^2Kt}{1 + AKt} \qquad [3]$$

with K again a rate constant and A the maximum proportion of recoverable mineral. Eq 3 may be

* At zero time recovery is zero; as time becomes large, recovery reaches a maximum.

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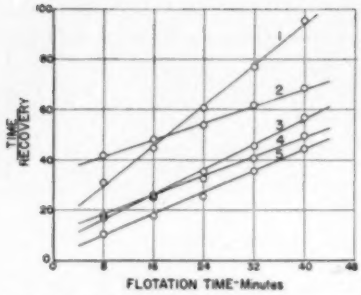

Fig. 1—Graphical test of second order rate equation. Data of Garcia Zuniga.

1—Coniapo gold ore
2—Gold flotation tailing
3—Elisa de Bordo silver ore
4—Oxidized copper
5—Sulphide copper

arranged as follows:

$$t/R = 1/A^2K + t/A \qquad [4]$$

If the second order equation is valid, a plot of (cumulative flotation time)/(cumulative recovery) against time should result in a straight line. It will be convenient to redefine a rate constant in terms of the recovery relative to the maximum possible recovery A. This constant then becomes A^2K** and will be the reciprocal of the intercept on a plot according to eq 4.

It will be shown that available data fit eq 4 with reasonable accuracy. However, it will also be shown that curve fitting, or the calculation of constants from the data, will not usually distinguish between first and second order equations when applied to flotation data. A more sensitive criterion is used which suggests the validity of the second order equation for the data available.†

Recovery Rate Data

This recovery rate data have been considered:

1—Zuniga's test results on five ores[2]
2—Beloglazov's test results on chalcopyrite and sphalerite[4]
3—Sutherland's test result on glass spheres[1]
4—Original test results as follows:
- a. Laboratory flotation of chalcocite ore *A*
- b. Laboratory flotation of chalcocite ore *B*
- c. Laboratory flotation of malachite-quartz mixtures
- d. Continuous flotation of sphalerite from massive sulphide ore
- e. Continuous flotation of chalcocite from low grade ore
- f. Continuous flotation of molybdenite from low grade concentrate

To obtain the laboratory data in this investigation, concentrate samples were collected through timed intervals, and the recoveries as functions of time were calculated from the individual concentrate assays and weights and the composite feed assay. For the continuous flotation of the sphalerite ore, tonnage and assay data were supplied which permitted calculation of extractions for each cell. For the continuous flotation of chalcocite, only time samples of the cell concentrates were available so that relative rather than absolute recovery values were used. For the molybdenite flotation, time samples of cell concentrates as well as samples of cell feed and final tailing were obtained. Cell recoveries were calculated from appropriate assays and weights. Cell residence times in the sphalerite flotation were supplied. For the chalcocite and molybdenite circuits the times are estimates from tonnage and volume data. The complete data are listed in Table I, with recoveries expressed in decimal form.

Testing Data

The data are plotted according to the criterion of eq 4 (t/R against t) in Figs. 1 through 9. These show a reasonably close agreement to the linearity required by the second order equation. *The method of plotting becomes insensitive at longer flotation times. Hence agreement of the earliest points with the straight line is a necessary condition for the graphical test to be significant.* For two of the continuous flotation results plotted in Figs. 7 and 8, several of the early points deviate considerably from the straight lines. In each case this was associated with a restricted rate of frothing because of conditioning or concentrate grade requirements.

The first order equation cannot be tested graphically in its integrated form. Algebraic tests, involving the calculation of constants from the data and reproduction of the experimental curve, show in some cases as good a fit as that obtained with eq 4, in other cases a poorer fit. This approach does not permit a decision between the two equations.

The ambiguity is caused by the fact that in most flotation circuits or batch tests a large proportion of the floatable mineral is recovered in the first cell of the bank, or in the first flotation interval. The nature of the remaining portion of the recovery-time curve is such that several equations will approximate it.‡

In chemical kinetics, when such uncertainty exists because of side reactions or experimental inaccuracies, the order of a reaction is determined by the relationship between reaction rate and initial reagent concentration.[7] For a first order reaction, the fraction of material decomposed after any fixed time is independent of the initial reagent concen-

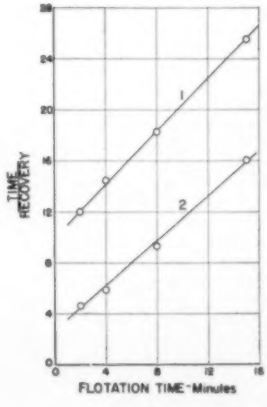

Fig. 2—Graphical test of second order rate equation. Data of Beloglazov.

1—Sphalerite
2—Chalcopyrite

** Rate $= A^2K(1-R/A)^2$

† Subsequent to the development and testing of the second order equation, it was found that Volkova[6] through an analytical approach had suggested that an equation similar in form should apply under certain conditions. Although he gave no experimental confirmation, Volkova's publication antedates the present investigation.

‡ An equation of the form $Rt = A + Bt$ will reproduce the major part of many recovery-time curves but is inconsistent with the condition that recovery must be zero at zero time.

Table I. Recovery-Time Data

Experiment Identity	Time, Min	Recovery				
Zuniga		Conispo Gold Ore	Gold Tailing	Silver Ore	Oxide Copper	Sulphide Copper
	8	0.475	0.191	0.445	0.200	0.792
	16	0.627	0.333	0.652	0.358	0.895
	24	0.683	0.445	0.745	0.398	0.907
	32	0.702	0.521	0.792	0.416	0.910
	40	0.706	0.584	0.808	0.420	0.910
Beloglazov			Chalcopyrite	Sphalerite		
	2		0.434	0.166		
	4		0.677	0.277		
	8		0.862	0.439		
	15		0.939	0.589		
Sutherland		Glass Spheres (52x72 Mesh)				
	0.5	0.388				
	1	0.714				
	2	0.821				
	3	0.870				
	4	0.896				
	5	0.910				
Copper A		Copper	Iron	Copper	Iron	
		(Lab Machine 1)		(Lab Machine 2)		
	1	0.632	0.353	0.561	0.237	
	2	0.756	0.433	0.711	0.335	
	3			0.773	0.381	
	4	0.815	0.496	0.800	0.406	
	6	0.831	0.528	0.822	0.435	
	8	0.840	0.551	0.833	0.453	
	10	0.850	0.573	0.840	0.475	
	12	0.860	0.592	0.846	0.493	
Copper B		Copper	Iron			
		(Lab Machine 1)				
	0.5	0.491	0.394			
	1	0.649	0.537			
	2	0.755	0.663			
	4	0.818	0.734			

Continuous Flotation	Sphalerite			Chalcocite — Low Grade Ore		Molybdenite from Low Grade Concentrate	
	Cell No.	Time, Min	Recovery	Cell No.[c]	Recovery[b]	Cell No.[c]	Recovery
	2	1.7	0.1475	1	0.477	1	0.381
	3	3.3	0.5298	2	0.488	2	0.471
	4	5.0	0.5953	3	0.578	3	0.574
	5	6.6	0.6300	4	0.848	4	0.649
	6	8.3	0.6505	5	0.900	5	0.694
	7	9.9	0.6607	6	0.940	6	0.721
	8	11.4	0.6659	7	0.966	7	0.741
	9	13.0	0.6710	8	0.980		
	10	14.4	0.6750	9	0.989		
	11	15.9	0.6776	10	0.994		
				11	0.997		
				12	1.000		

[a] Total flotation time 4 min.
[b] Relative.
[c] Total time 7 min; assumed equally distributed because of high ratio of concentration.

Table II. Effect of Feed Assay Variation on Recovery

Feed Assay, Pct Copper	1.11	0.86	0.28	0.21	0.12
Concentrate Assay, Pct Copper	21.07	10.35	9.85	3.51	2.81
Tailing Assay, Pct Copper	0.062	0.090	0.070	0.12	0.089
Ratio of Concentration	21.1	21.8	46.0	26.4	46.2
Extraction	92.9	84.7	75.8	45.2	30.2

[a] Feed assay variation obtained by preparation of quartz-malachite mixtures containing indicated copper percentages; pulp preparation and treatment were otherwise identical in all tests.

Table III. Tabulation of Rate Constants

	Ore or Mineral	Rate Constant		Ore or Mineral	Rate Constant
1[a]	Gold ore	0.08	4	Ore A, machine 1	
1	Gold tailing	0.03		Copper	2.5
1	Silver ore	0.2		Iron	0.7
1	Oxide copper	0.1	5	Ore A, machine 2	
1	Sulphide copper	1.7		Copper	2.0
2	Chalcopyrite	0.4		Iron	0.4
2	Sphalerite	0.1	6	Ore B, machine 1	
3	Glass spheres	2.5		Copper	2.1
				Iron	1.5
			7	Chalcocite	2.9
			8	Sphalerite	0.6
			9	Molybdenite	0.5
			9	Copper	0.006

[a] Refer to Figure of same number.

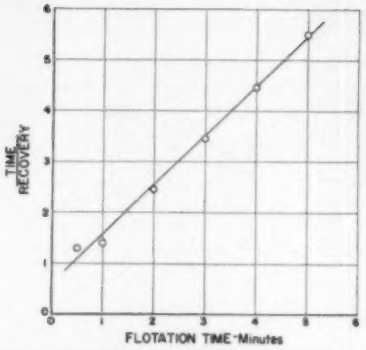

Fig. 3—Graphical test of second order rate equation. Sutherland's data on glass spheres.

tration. On the other hand, the fraction decomposed in a second order reaction will depend on the initial concentration. These same relationships apply to the flotation rate equations since they derive from the form of the equations and not from any assumptions about the mechanism of the process. The initial mineral concentration can be varied either by variation in feed assay or by variation in pulp density at constant feed assay.

Table II contains data illustrating the effect of feed assay variation on the recovery of copper from mixtures of malachite and quartz. The qualitative dependence of recovery on initial mineral concentration is indicated. Similar effects are described for feed assay variation with Climax molybdenum ore[9] for pulp density variation with galena-granite mixtures[9] and galena-quartz mixtures.[10]

This argument leads to the following conclusions:

1—A second order equation rate can be used to reproduce experimental flotation-recovery/time curves.

2—Rational support for a second order equation is supplied by instances of the dependence of recovery on initial mineral concentration. However, the limited amount of data of this type suggests that decision on the actual order of the rate equation be reserved.

For the purpose of this investigation, which deals with the use of rate constants in performance evaluation, the second order equation will be used.

Rate Studies Potentialities

The study of flotation rates can provide two types of information. First, knowledge of the order of the rate equation may lead to a better understanding of the mechanism of the process. Sutherland's attempt to establish that bubble-particle collision is rate determining, although not conclusive, indicates the approach. It may be possible through rate studies to determine whether such collision is involved, whether as Sun reports[11] multi-bubble aggregates can occur, and whether particle-particle collision can be rate-determining.[12] In addition, there is the possibility that the rate constant can be related to the contact angle, particle size, bubble size, and surface reagent concentration. Thus the rate approach may be able to integrate the fundamental flotation variables with those that measure the results of the separation.

In the second place, rate studies can be of direct use in evaluating performance. The rate constant is particularly suited to this purpose. Table IV lists such constants for the recovery data in Table I. They were obtained either by extrapolation or by conventional algebraic methods.§ It has been indicated

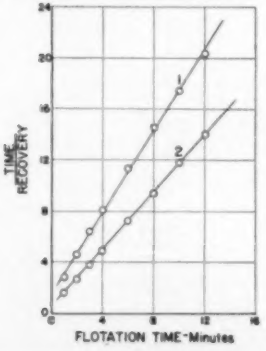

Fig. 4—Graphical test of second order rate equation. Copper ore A, laboratory flotation machine 1.

1—Iron
2—Copper

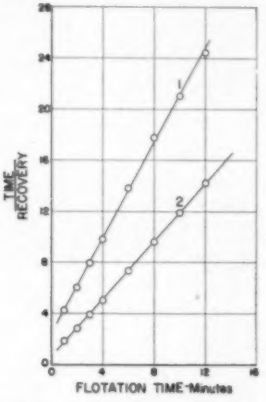

Fig. 5—Graphical test of second order rate equation. Copper ore A, laboratory flotation machine 2.

1—Iron
2—Copper

that the rate constant will be affected by changes within either of the two groups of variables controlling the process. To the extent that the data permit, the following discussion illustrates the effect of such changes.

Rate Constant in Performance Evaluation

Variation in Ore and Ore Treatment: The rate constants listed in Table III range from 0.008 to 2.5, the variation being caused by variations in the minerals, in their treatment, and in the machines used. Differences between minerals may be caused by differences in those physical properties which affect particle size and shape in subsequent size reduction, or to a different response to reagent treatment. Zuniga's data show a wide variation in rate constant between a sulphide copper mineral in an ore and gold in a tailing, the former having a constant of 1.7 and the latter a constant of 0.03. Copper ores *A* and *B*, both containing chalcocite but from different operations, gave constants of 2.5 and 2.1 in the same machine and with similar reagent treatment. On the other hand, another sample of ore *A* gave a constant of 1.4, illustrating the significant differences in rate between samples from the same orebody.

§ In terms of eqs 3 and 4, the relative rate constant A^2K is equal to $\frac{R_1R_2}{t_1\ t_2}\frac{(t_2-t_1)}{(R_2-R_1)}$, where R_1 and R_2 are the recovery values at t_1 and t_2.

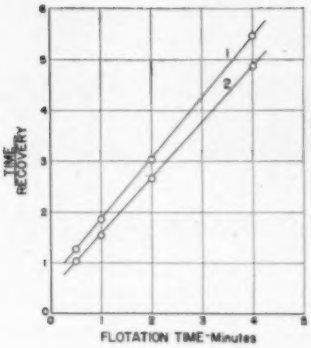

Fig. 6—Graphical test of second order rate equation. Copper ore B, laboratory flotation machine 1.

1—Iron
2—Copper

For two minerals floating from the same pulp the ratio of rate constants is a logical measure of selectivity.[4] It should be affected by any change in treatment which affects the rate for either mineral. The data in Table IV yield the following selectivity ratios, which are valid in each case only for the conditions used:

Chalcopyrite/sphalerite (Beloglazov)	4.0
Chalcopyrite/pyrite (Ore *A*, machine 1)	3.6
Chalcopyrite/pyrite (Ore *A*, machine 2)	5.0
Chalcopyrite/pyrite (Ore *B*, machine 1)	1.4
Molybdenite/copper	63

The selectivity ratio as defined above is closely related to Gaudin's Selectivity Index,[12] which was proposed without specific reference to relative flotation rates. For two minerals both of which are assumed to be completely floatable but at different rates, the ratio of rate constants at any time is $\frac{R_1}{1-R_1} \times \frac{1-R_2}{R_2}$, while Gaudin's Index is the square root of this ratio.

Variation in Machines: The selection of flotation machines for any operation is usually made on the basis of comparative tests.[13] Important contributions in quantifying machine performance have been made by Rose[14] and by Myers and Lewis.[15] The rate approach offers the possibility of integrating performance with capacity, and of providing a single number index for comparing machines.

For a separation in any machine the rate constant as already indicated will depend on the ore and its pretreatment as well as on the machine. The machine contribution cannot be isolated for the single system. However, if the identical pulp is treated in another machine, the ratio of rate constants will be a relative measure of the contribution of each machine to the rate. Thus copper ore *A* gave a constant of 2.5 in machine 1, and of 2.0 in machine 2. For machine 1, treating ore *A* in a laboratory batch test, the rate constant was 2.6; for mill cells of the same design, treating similar but not identical pulp, the constant was 2.9.

If, for simplification, it is assumed that the maximum possible recovery with a given pulp is close to unity, eq 3 becomes

$$Kt = R/(1-R)$$

Since tonnage capacity is inversely proportional to the flotation time requirement, then at a fixed recovery level the capacity will be directly proportional to the rate constant. Hence the ratio of rate constants for the same pulp in two different machines will be equal to the ratio of capacities obtainable with the two machines for the same recovery. On the other hand, the ratio of rate constants for constant tonnage through the two machines on the same pulp will be related to differences in recovery.

Machines also may be rated according to selectivity rather than according to the rate for one mineral. In laboratory flotation of ore *A*, the copper/iron selectivity was 3.6 for machine 1, and 5.0 for machine 2, indicating that the first machine makes a higher extraction at any time but at the expense of lower selectivity.

Capacity, Power, and Rate Constant

It has been indicated that the second order rate equation where valid leads to a direct proportionality between rate constant and cell capacity at a fixed recovery level. Rose has shown[16] that cell capacities within a group of 14 operations varied in an approximate linear manner with power intensity (horsepower per cubic foot of cell volume). For a first approximation, as Rose suggested, power intensity is more important in determining rate than ore, ore treatment, and machine design. However, the deviations from the linear relationship, and the fact that in any one machine differences in rate constants for different ores are obtained, suggest that the secondary effects cannot be neglected in a complete analysis. The role of power intensity in controlling the rate constant can be related to its effect of power on aeration and on sand suspension.[4]

Aeration: For mechanical cells an increase in power intensity caused by increased impeller speed results in increased aeration, although not at a constant rate (unpublished data). A similar condition should exist for pneumatic cells. Total air input, however, is not a sufficient measure of the effectiveness of air in flotation, since bubble size must be considered. Cooper[18] has shown that the efficiency of air in oxidizing sodium sulphite solutions, which depends on both total air volume and bubble size, is directly proportional to agitator power intensity at constant air input. Similarly, Foust[17] found that bubble dispersion, with constant air input to an agitated vessel, varied with the square root of power intensity.

For flotation cells, Myers and Lewis[15] report aeration intensity and power intensity data which indicate a fourfold variation in aeration per unit of power between the extreme values. Thus, while aeration quantity and quality may depend principally on power intensity, machines will differ in the efficiency of power utilization for aeration.

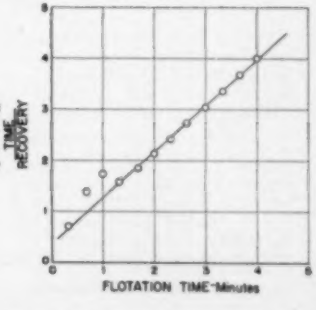

Fig. 7—Graphical test of second order rate equation. Continuous flotation, low grade copper ore.

Sand Suspension: Sand suspension by mechanical agitation has been studied to develop a criterion for agitation intensity.[17] The principal findings were that in the size range 32 to 100 mesh suspension depends quantitatively on sand size and impeller speed. For any size in this range increased impeller speed progressively increases suspension until it is complete. The speed necessary for complete suspension increases directly with sand size. It was also found (and confirmed in this investigation on an operating flotation cell) that suspension is not necessarily uniform, even though complete. Although no comparative data on sand suspension for flotation cells are available, it is to be expected that cells will differ in this respect just as with respect to aeration.

Flotation Efficiency

The efficiency of a flotation cell is related to the return in aeration and sand suspension per unit of power expended. No general relationship is known between the flotation result on the one hand and a measure of either aeration or sand suspension on the other. Moreover, increased aeration and sand suspension are useful only to the extent that performance continues to improve. The rate constant, therefore, which is a direct measure of performance, is a logical index of efficiency when related to the power expended. In other words, one machine is more efficient than another when it develops a higher rate constant for the same energy expenditure on the same pulp.[§§]

Summary

It is shown that flotation results can be analyzed in terms of rates, and that a rate constant in a second order rate equation is a useful measure of performance. The ratios of such constants can yield relative measures of the contributions of both pulp and machine to the rate. The ratio of the rate constant to the energy expenditure is proposed as a measure of flotation efficiency.

This approach to the analysis of the flotation process is based on the hypothesis that a mineral has a potential floatability determined by its previous treatment and that the machine realizes this floatability through the medium of pulp suspension and aeration. The floatability of the mineral cannot be defined precisely except in terms of the actual flotation result; similarly, the machine contribution, although related to power intensity within limits, is best defined in terms of the operation. The further analysis of rates and determination of rate constants should aid in clarifying these relationships and in advancing the efficiency of the process.

§§ This index will have the dimensions: Recovery-tons /hour /horsepower hour if the customary horsepower hours/ton is used to relate tonnage with energy.

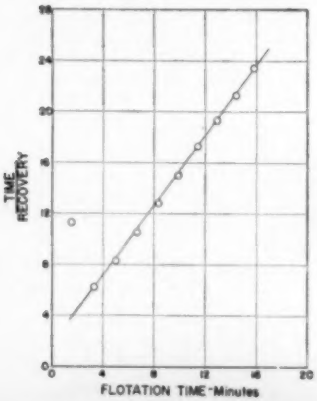

Fig. 8—Graphical test of second order rate equation. Continuous flotation, sphalerite from massive sulphide ore.

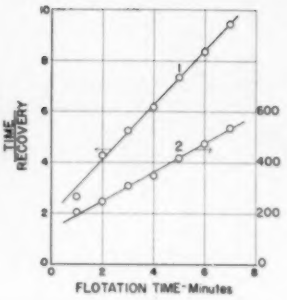

Fig. 9—Graphical test of second order rate equation. Continuous flotation, molybdenite from low-grade concentrate.

1—Molybdenite
2—Copper

Acknowledgments

Appreciation is expressed to W. H. Osborn, Director of Development and Research, Phelps Dodge Corp. for encouraging this work and permitting its publication, to J. F. Myers and F. M. Lewis of the Tennessee Copper Co. for furnishing the sphalerite rougher data, and to numerous associates for encouragement and suggestions.

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Magnetic and Chemical Analyses Of Ores and Mill Products Containing Magnetite and Ilmenite

by Erkki Laurila, O. Jantti, and R. T. Hukki

INVESTIGATION of the methods of analyses for magnetite and ilmenite in the Otanmäki iron-titanium ore and respective mill products has resulted in certain improvements in the methods conventionally employed. The outcome of the investigations is summarized as follows:

1—Development of a diamond-drill core analyser for the determination of magnetic susceptibility of drill cores containing magnetic minerals.

2—Development of a magnetite-ilmenite analyser for pulverized products.

3—Development of a potentiometric method of chemical analysis for the determination of iron, vanadium, and titanium in succeeding steps from one test sample.

4—Proposal for a continuous and automatic magnetite assay method.

Diamond-Drill Core Analyser

The conventional method of assaying diamond-drill cores consists of splitting the cores, pulverizing them and running chemical analyses on representative samples. The physical properties of magnetic minerals, however, offer an entirely different approach to obtain similar final result by the measurement of respective magnetic susceptibilities in a properly designed instrument.

This instrument is shown in Fig. 1. Essentially it consists of a magnetic unit, *A*, and of a meter unit, *B*. On top of *A* is a slot where a piece of diamond-drill core *C* is visible. The magnitude of disturbance in the original magnetic field caused by the magnetic minerals in the drill core can be observed from the microammeter. This reading is a function of the combined susceptibilities of all magnetic grains in the magnetic field.

The magnetic unit is built of E-sheets of a shell transformer, as shown in Fig. 2. The primary coil and two identical secondary coils are wound around the central leg and end legs, respectively. The drill core under examination is placed into one of the air gaps as shown in Fig. 2. The number of ampere-turns of primary coil excited by 50 or 60-cycle ac give a maximum induction of about 600 gauss in the air gaps. The secondary coils are connected in series in the opposite direction. Thus their voltages compensate each other if no drill core exists in the air gap or if the susceptibility of the drill core is equal to zero. As soon as the susceptibility becomes greater than zero, the balance of the magnetic circuit is disturbed, resulting in increased voltage in the terminals of coil 1 and in a respective decrease of voltage in the terminals of coil 2. The voltage difference thus produced is a function of the effective susceptibility of the drill core. If the magnetic grains in the drill core are unevenly distributed, the voltage difference varies as the core is rotated around its own axis.

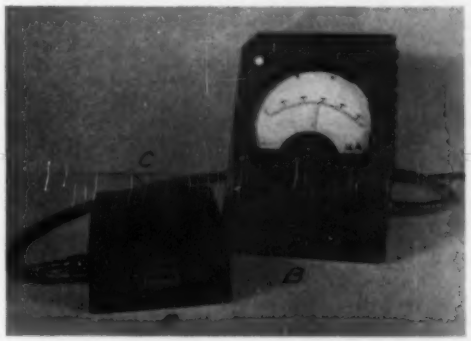

Fig. 1—Diamond drill core analyser.

The voltage difference is measured with a Brentano tube voltmeter. If extreme sensitiveness is desired, the established symmetry of the magnetic circuit does not allow reduction of the O-voltage difference far enough. Therefore a compensatory voltage of a correct phase taken from the terminals

E. LAURILA, Professor of Technical Physics, and R. T. HUKKI, Member AIME, Professor of Mineral Dressing, are with the Finland Institute of Technology, Helsinki. O. JANTTI, Chemist, is with the Chemical Laboratory of Finnish Defence Forces, Helsinki.

Discussion on this paper, TP 3113B, may be sent to AIME before Sept. 28, 1951. Manuscript, Nov. 20, 1950. New York Meeting, February 1952.

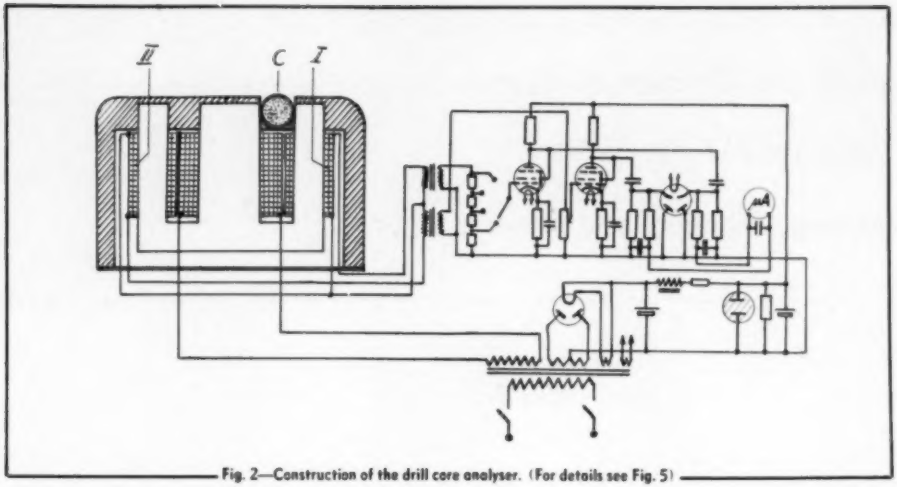

Fig. 2—Construction of the drill core analyser. (For details see Fig. 5)

of one of the secondary coils is connected to the grid of one tube of the tube voltmeter. With this arrangement it has been possible to include four scales of sensitiveness in sequence of 1:4:16:64. The least sensitive scale is used for cores containing magnetite. A core 22 mm in diam of relatively pure magnetite causes a reading of about 80 pct of the available scale. The lowest value of susceptibility that can be observed with the most sensitive scale is of the order of 0.001.

The electronic system of the drill core analyser is shown in Fig. 2.

To test the instrument, a box containing one drill core representing the Otanmäki ore and wall rocks was received. Nine samples were selected from it to cover as wide a range of analyser readings as possible. Two cores representing O-reading were selected because of differences in mineral composition. Each sample core selected was tested in the analyser with the least sensitive scale. Readings were taken in 5-mm steps between two chosen end marks. For each reading the core was rotated 360°, the maximum and minimum readings were recorded and averaged. Their average was taken as the final reading for the whole sample. The cores were cut at the end marks, pulverized, and assayed by the chemical method described later. Table I indicates the results obtained. Analyser readings vs. total iron contents are shown in Fig. 3.

Table I. Magnetic and Chemical Analyses of Samples of a Diamond-Drill Core

Drill Core	Analyser Readings			Total Fe, Pct			TiO_2, Pct		
	Max	Min	Avg	a	b	Avg	a	b	Avg
1	0	0	0	13.25	13.25	13.25	5.89	6.01	5.95
2	0	0	0	12.87	13.11	12.99	6.14	5.70	5.92
3	10	30	20	15.32	15.41	15.36	1.57	1.50	1.53
4	40	80	57	23.19	23.09	23.14	7.46	7.36	7.41
5	65	125	94	28.40	28.47	28.43	9.48	9.34	9.41
6	125	190	162	34.77	34.40	34.58	10.51	10.64	10.57
7	110	270	218	43.26	43.10	43.17	17.38	17.28	17.33
8	205	260	239	45.55	46.08	45.81	15.41	15.42	15.41
9	225	270	255	48.55	48.91	48.73	15.64	16.12	15.83

Table II. Susceptibilities of Otanmaki Magnetic and Ilmenite

Max Field Strength, Amp-Turns per M	Susceptibility of Magnetite	Susceptibility of Ilmenite
500	2.80	
5000	3.35	0.025
25000	2.60	0.030
50000	2.05	0.022
100000		0.016

As can be seen from Fig. 3, the points fall nearly on a straight line. Whether the relationship follows a straight line or a curve depends on the type of ore. Should magnetite be the only iron-bearing mineral, a straight line relationship is to be expected. In the case of Otanmäki ore the analyser reading on the abscissa is affected slightly by the presence of ilmenite, and the value of total iron on the ordinate includes in addition to magnetite such iron-bearing minerals as ilmenite, pyrite, hornblende, etc. Their distribution in the ore does not depend on that of magnetite. Before the true average shape of the graph in this case can be presented with certainty, a substantial number of experimental values is required.

The analyser offers a rapid and inexpensive method for preliminary analysis of drill cores carrying magnetic minerals. It obviously is best suited for ores where magnetite is the only iron-bearing mineral. No great accuracy can be claimed mainly because of unavoidable variations in core diameter. Since the diamond-drill core itself, even with the best possible recovery, represents only an approximation of the respective rock; and the splitted halves are an approximation of the cores recovered; the drill-core analyser method, which takes into account the entire core available (if readings are taken in close enough steps) probably represents the same order of accuracy as can be claimed for the conventional method. In field use, the analyser can reduce materially the number of chemical assays required, but it is not expected to replace them al-

together. Results of magnetic and chemical analyses of samples of a diamond-drill core of Otanmäki are given in Table I.

Magnetite-Ilmenite Analyser

In assaying pulverized products containing magnetite, the use of a magnetic analyser such as the Davis magnetic tube tester is a well-known and widely accepted practice. In the Davis instrument the magnetic particles of a weighed sample are held inside a water-filled glass tube by a strong dc electromagnet, or more recently by a permanent magnet, while the nonmagnetic particles are thoroughly removed by the combined actions of gravity, reciprocation of the tube, and wash water. Either the magnetic fraction retained or the nonmagnetic fraction removed is dried and weighed to obtain the amount of magnetite in the original sample.

In the case of Otanmäki ore it was desirable to develop an instrument in which the physical evaluation of magnetite content of pulverized samples could be followed by a similar evaluation of ilmenite content of at least such products as ilmenite concentrate and ilmenite tailing.

The physical evaluation of magnetite and ilmenite is based on their magnetic properties. The susceptibilities of carefully prepared −100 mesh samples of high grade Otanmäki magnetite and ilmenite measured in ac magnetic fields are shown in Table II.

Two methods for the evaluation of magnetite and ilmenite of the same sample are possible, theoretically at least. One of them could be based on two determinations of susceptibilities of a sample in two magnetic fields of widely different strengths. The other could be based on magnetic separation of magnetite and ilmenite into separate fractions. The method described here is based on the second principle. The evaluation of the amount of magnetite and ilmenite in the respective fractions is done by electrical instruments.

Model No. 2 of the analyser developed is shown in Fig. 4 and its construction in Fig. 5. Essentially the instrument consists of a magnetic unit, *A*, and a meter unit, *B*.

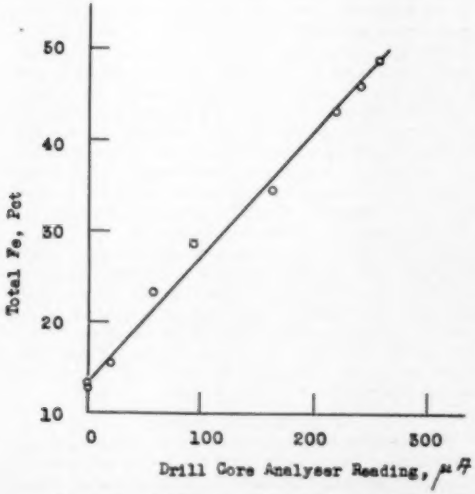

Fig. 3—Plot of drill core analyser readings vs. total iron content.

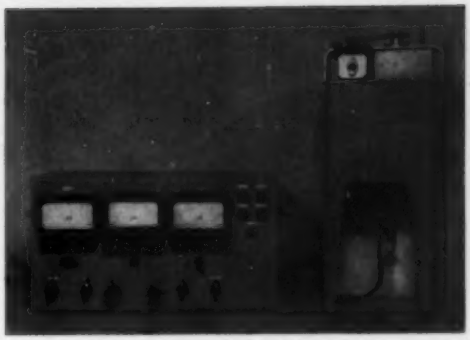

Fig. 4—Magnetite-ilmenite analyser.

A pulped sample is introduced through the funnel of a slowly revolving distributor into a vertical glass tube filled with water. The magnetite fraction of descending particles is held against tube walls by an inhomogeneous magnetic field produced by an ac excited magnet resembling in construction a "magnetic lens." The strength of the field holds all particles of magnetite but no ilmenite. The tube is surrounded also by a secondary coil in which the retained magnetite induces a voltage the value of which is a function of the amount of magnetite present. This voltage is indicated in the meter unit by a tube voltmeter.

The ilmenite fraction is held by a strong ac magnetic field of the type used in the drill-core analyser described above. The ilmenite retained causes a change in the flux of the magnetic field resulting in a change in the voltage difference of secondary coils.

Because the voltage differences in the magnetite and especially in the ilmenite coils are small and the impedance of the coils relatively large, the voltages are measured by tube voltmeters. The meter in the magnetite circuit is a tube voltmeter of Brentano type. The voltage to be measured is connected to the grid of one tube and a compensatory voltage from a separate transformer to the grid of the other tube of the voltmeter. Thus the indicated reading is equal to zero if no magnetite exists in the analyser tube. In the ilmenite circuit this arrangement is not satisfactory, but a two-stage tube voltmeter is necessary. The first stage is the same as described above in connection with the drill-core analyser. Its output is rectified by a diode circuit and is connected to the second stage operated as a dc amplifier. To obtain sufficient stability, all amplifier circuits have a strong negative feedback. The complete wiring diagram of the magnetite-ilmenite analyser is shown in Fig. 5.

To test the instrument (Model No. 2), two samples of −100 mesh high grade magnetite and ilmenite were used. For magnetite the upper curve shown in Fig. 6 was obtained. The nonlinear scale is intentional because greater accuracy was desired for small amounts of magnetite. The lower curve in Fig. 6 represents similar readings for ilmenite samples containing no magnetite. Because specially prepared clean samples were used, the above calibration curves are of theoretical value only. They clearly show, however, the basic characteristics of the instrument.

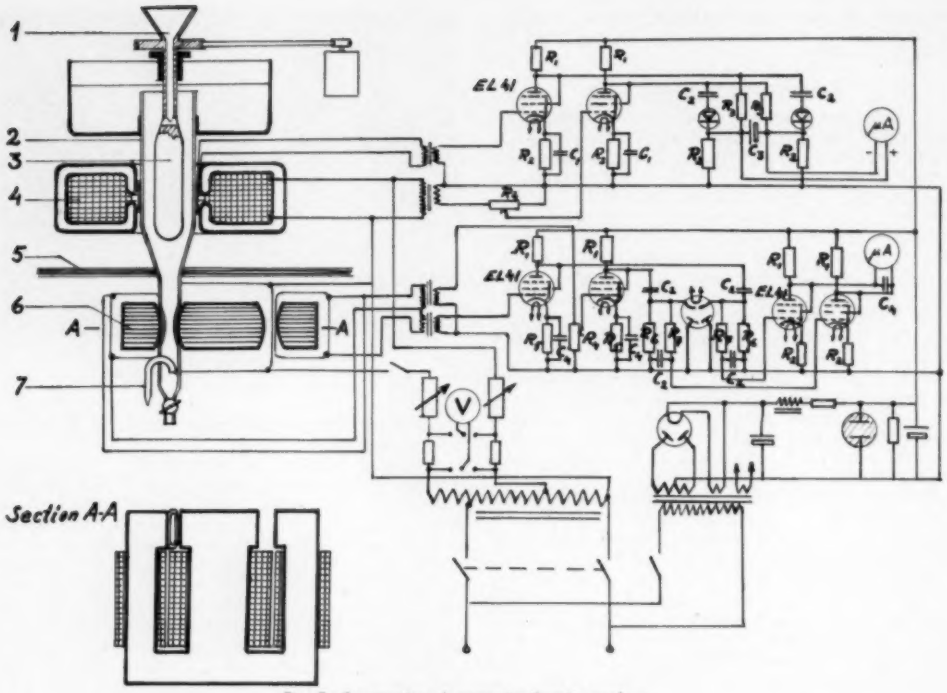

Fig. 5—Construction of magnetite-ilmenite analyser.

1. Funnel
2. Glass Tube
3. Distributor
4. Magnetic circuit for magnetite
5. Magnetic shield
6. Magnetic circuit for ilmenite
7. Discharge tube

R_1 — 40 k Ω
R_2 — 5 k Ω
R_3 — 70 k Ω
R_4 — 1 k Ω
R_5 — 2.5 k Ω
R_6 — 200 k Ω
R_7 — 65 k Ω

C_1 = 50μF
C_2 = 0.5μF
C_3 = 100μF
C_4 = 50μF

Actual mill products of Otanmäki ore all contain a mixture of varying amounts of magnetite, ilmenite, and a score of nonmagnetic gangue minerals. To meet the practical conditions of everyday drift samples, a new set of calibration curves must be prepared including all classes of samples that are to be analysed by this method.

Our experience indicates that no particular difficulties were encountered in the magnetite analyses of actual mill products. As a matter of fact, Model No. 1 of this instrument has operated satisfactorily for several months in the Otanmäki pilot plant. The presence of ilmenite or gangue or locked particles of any kind within the magnetite retained is not a disturbing factor in magnetite determinations because the susceptibilities of other minerals are small compared with that of magnetite. If they have an effect, it is small and consistent within each class of samples.

A correct determination of ilmenite simultaneously with magnetite requires that all ilmenite particles report in the ilmenite circuit. This condition hardly can be fulfilled in analysing magnetite concentrates containing small amounts of ilmenite. The interlocking of even a small fraction of the ilmenite within the large bulk of magnetite is enough to cause serious errors in the amount of ilmenite reporting in the lower field. With ilmenite concentrate and ilmenite tailing samples containing little or no magnetite, the conditions stated above can be met either without any precautions or with a pretreatment of the sample to be analysed in a small additional ac magnetic separator unit of such construction as to allow the magnetite-free fraction to fall into the analyser tube ahead and the substantially clean magnetite fraction immediately behind.

The magnetite-ilmenite analyser developed has the following advantages when compared with the conventional magnetic tube tester method: 1—Two magnetic minerals of different susceptibilities can be separated for physical evaluation. 2—The ac magnetic field used cause a strong cleaning effect through the intense vibration of the magnetic particles in the field. 3—The amount of magnetic mineral reporting in each circuit is evaluated by electrical instruments. 4—The instruments do not record the presence of gangue minerals whether in free or locked particles. 5—The final results are obtainable within a minute or two.

Potentiometric Analysis

The simultaneous presence of iron, vanadium, and titanium in mill products of Otanmäki ore has introduced certain difficulties especially in the accurate chemical determinations of vanadium and titanium.

Two methods[1, 2] have been recently described by which iron and titanium can be volumetrically determined from one solution. No description including all three was discovered. The method presented here for the determination of iron, vanadium, and titanium is primarily based on the paper of Lingane[2].

Principle: A sample containing V^{+++++}, Fe^{+++} and Ti^{++++} ions in sulphuric acid medium is titrated with a titrant of chromous sulphate. The change of potential indicated by a potentiometer plotted against titrant added gives a curve shown in Fig. 7. In it the first major fall represents reduction of V^{+++++} to V^{++++}, the second one simultaneous reduction of Fe^{+++} to Fe^{++} and V^{++++} to V^{+++}, and the third one reduction of Ti^{++++} to Ti^{+++}. The amount of vanadium in the original sample is obtained by evaluation of titrant used for the first fall of potential up to the first inflexion point in the curve; this reading is multiplied by factors related to the normality of titrant and to the chemical formula with which the final result is to be expressed. The amount of iron in the sample is obtained similarly by evaluation of the amount of titrant used for the second fall of potential between the first and second inflexion points subtracted by a correction factor equivalent to the amount of titrant used for the reduction of V^{+++++} to V^{++++}. This correction takes care of the reduction of V^{++++} to V^{+++}. The difference is multiplied by respective factors for iron for final result. The amount of titanium is obtained by evaluation of the amount of titrant used between the second and third inflexion points and by multiplying this value with respective factors. The paper of Lingane[2] may be consulted for detailed physicochemical discussion of the method for iron and titanium as well as for apparatus necessary to automatice the procedure.

Apparatus: The apparatus used is shown in Fig. 8. It consists of two identical systems to allow simultaneous titration of one sample and removal of oxygen by CO_2 gas of another sample. Titration takes place under CO_2 atmosphere. The change of potential is observed from a potentiometer not included in Fig. 8.

Procedure: A 400-mg sample is mixed in a nickel crucible with 5 g of Na_2O_2 and fused carefully for 10 min. The hot crucible is dipped halfway into water

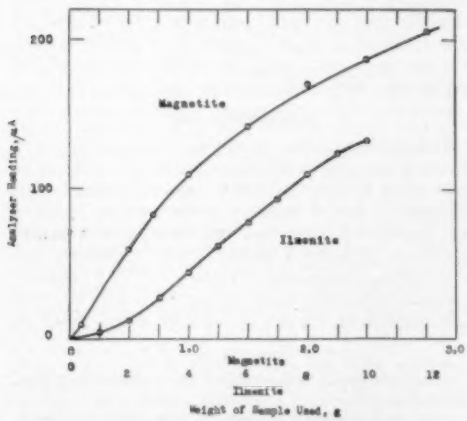

Fig. 6—Plot of calibration curves of magnetite-ilmenite analyser.

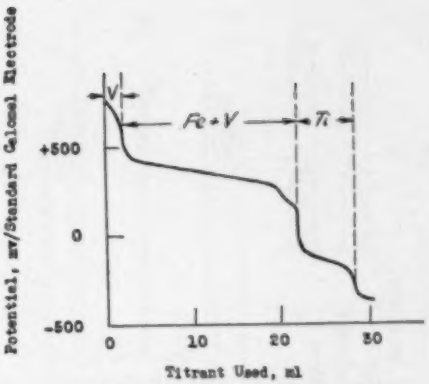

Fig. 7—Potentiometric titration of +3 iron, +5 vanadium and +4 titanium with chromous ion.

and placed upside down on top of glass sprinkler, *11* (Fig. 8), in a 400-ml beaker. Through the sprinkler is poured 60 ml of boiling water followed by 50 ml of hot sulphuric acid (1 + 1). The crucible is removed. A few drops of 3 pct H_2O_2 are added to dissolve precipitated MnO_2. Solution is boiled for 5 min and cooled down to room temperature. The beaker is placed for titration position and covered tightly. Oxygen-free CO_2 is bubbled through the solution for 20 min and continued during titration to remove oxygen. Vanadium and iron are titrated by using platinum indicator electrode against calomel reference electrode. When equivalence point potential is reached, the platinum electrode is lifted out of solution, the mercury indicator electrode is inserted, and operation is continued beyond the third inflexion point.

Reagents: Amalgamated zinc is prepared by treating 1 kg of analytically pure zinc for 10 min in a solution consisting of 28 g of $HgCl_2$, 100 ml of HCl (1.19) and 500 ml of water. After the treatment the zinc is washed free of chlorides. The storage flask *2*, (Fig. 8), is fully filled with the amalgamated zinc thus obtained.

The titrant is prepared in a 1½ to 2-liter conical beaker by dissolving 38.84 g of $K_2Cr_2O_7$ in 200 ml of water, after which 65 ml of H_2SO_4 (1.84) and finally 75 ml of 30 pct H_2O_2 are carefully added. Solution is kept boiling for 30 min, cooled down and diluted in a volumetric flask to 2-liter volume. The storage flask, *2*, is filled with this solution 8 to 12 hr before use to allow time for complete reduction to chromous ion. With the purest zinc available the titrant could be preserved for a maximum of 1 week.

Wash solution of CO_2 is prepared by the same method as the titrant. It is diluted, however, to 500 ml only. Zinc in 200-ml wash bottles, *1* (Fig. 8), is covered with this solution about 12 hr before the apparatus is used. If CO_2 gas contains less than 0.2 pct by volume of oxygen this method of deoxidation is satisfactory.

The chromous sulphate titrant is checked against 0.1 molar $CuSO_4$ reference solution, of which 25 ml are mixed with 25 ml of water and 50 ml of HCl (1.19). The exact copper content of the reference solution is determined by electrolysis.

Electrodes and their care: A satisfactory platinum electrode consists of an 80-mm piece of 1-mm plati-

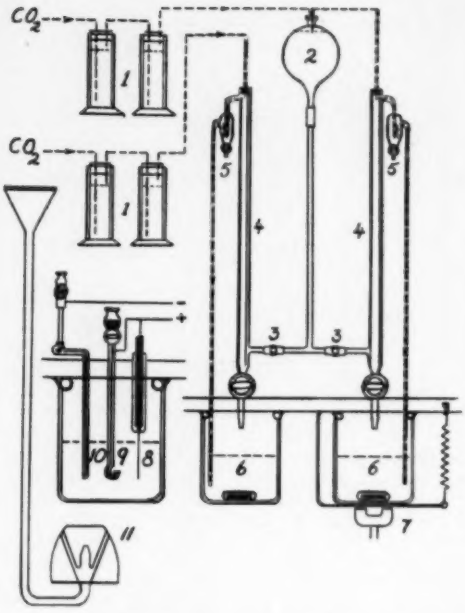

Fig. 8—Apparatus for potentiometric analysis of iron, vanadium, and titanium.

1. Wash bottles for removal of oxygen of CO_2 gas
2. Titrant storage flask
3. Glass bead valve
4. Burette
5. Removal of excess of titrant
6. Titration vessel
7. Magnetic stirrer
8. Platinum indicator electrode
9. Mercury indicator electrode
10. Calomel reference electrode
11. Sprinkler for removal of fused sample

num wire soldered to a thin brass rod. The rod is inserted in a glass tube permanently connected to the cover of titration vessel. The electrode thus can be removed easily for washing in HCl and ignition to secure its absolute cleanliness.

The construction of the mercury electrode is shown in Fig. 8. Analytically pure and gas-free mercury must be used. The platinum contact with mercury should be occasionally cleaned.

Discussion of Method

The potentiometric analysis of iron, vanadium, and titanium has given very satisfactory service in the chemical assaying of products of Otanmäki iron-titanium ore. As a matter of fact, the three constituents can be determined faster by this method than by any other method known to the authors. One determination from a pulverized sample requires normally 45 to 60 min. With the apparatus described above the (absolute) errors seem to be within the following limits (see also Table I): Fe, ± 0.3 pct; V_2O_5, ± 0.1 pct; TiO_2, ± 0.2 pct.

Because the amount of vanadium (V_2O_5) in all products assayed has been less than 1 pct, the (absolute) error of ± 0.1 pct is large. Vanadium can be determined with greater accuracy from a substantially larger initial sample. If a 5 g weighing is used (40 g Na_2O_2 for fusion and 100 ml 1 + 1 H_2SO_4 for dissolution), then the (absolute) error of V_2O_5 may be reduced to ± 0.02 pct.

Continuous Magnetite Assay

A fully automatic and continuous plant assay control system is the dream of many a millman. Numerous attempts have been made to solve the problem, but as far as the authors know none of them has been successful.

The magnetic instruments described in this paper seem to offer a marked step forward toward continuity, instantaneous evaluation, and exact recording of product assays. The following apparatus seems to be essential for the determination of magnetite:

1—Equipment to form continuous and representative sample bar of the pulverized product to be analysed. This bar corresponds to a diamond-drill core in the preceding discussion.

2—Magnetic unit through which the sample bar moves. In principle this unit is the same as the one used for diamond-drill core analyser.

3—Measuring and recording unit for the evaluation of the magnetic effect caused by the sample bar. The measuring unit would correspond to the respective unit of the drill core analyser. The recording instrument could be of the general type used in continuous recording, e.g. Micromax of Leeds & Northrup Co., Brown Electronik Potentiometer of Minneapolis-Honeywell Regulator Co.

No attempt has been made to put the necessary apparatus together. Cutting of a representative sample and formation of a uniform sample bar may prove to be the basic problem in the procedure suggested.

The products that could be assayed by the method described above include all powdered products of magnetite concentrators where magnetite is the only magnetic mineral. In the case of Otanmäki ore, where both magnetite and ilmenite occur in varying amounts in all products, the continuous assaying of products rich in magnetite should be possible. The adaptability of the method for magnetite tailing assays may or may not be feasible.

A combination of a continuous magnetic assay system with a continuous magnetic weightometer integrator system indicating the total effect of all magnetic particles in the concentrate produced would result not only in automatically recorded quality but also in automatically recorded quantity of the magnetite concentrate.

Acknowledgments

The investigations described above have been financed by Otanmäki Co. The instruments have been built in the Technical Physics Laboratory of the State Research Institute in Helsinki. In building the instruments we wish to record the valuable assistance given by H. Möller, Radio Technician and V. Rantala, Instrument Technician. The chemical investigations have been carried out in the Chemical Laboratories of Finnish Defence Forces in Helsinki.

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[1] B. A. Shippy: Determination of Titanium and Iron. *Analytical Chemistry* (1949) **21**, p. 698.

[2] James J. Lingane: Automatic Potentiometric Titration of Iron and Titanium with Chromous Ion. *Analytical Chemistry* (1948) **20**, p. 797.

Characteristics of Mechanized Mining Sections

by A. W. Asman and A. W. Bitner

An analysis is made of three different types of section production units that represent the manner in which most of the nation's bituminous coal is produced. The general delays and production characteristics of these sections are presented along with a method for evaluating section performance based on actual and theoretical production characteristics.

THE forerunner of the modern mechanical loading machine first entered the mines in 1890—a Stanley header with a conveyor. Since then progress has been substantial, both in the design and application of mechanized production units. Mechanization is almost a necessity for survival in the economy of today.

In this paper an analysis is made of three types of sections, and a method for evaluating section performance based on present production characteristics and theoretical characteristics is presented.

In mechanical loading mining sections the loading machine is the unit directly responsible for production. If the face preparation units provide a plentiful supply of properly prepared coal and the transportation system is coordinated and adequate, the loader will be idle a minimum of time. If either of the above do not perform adequately or other delays occur, the effect on production will be reflected in the performance of the loading machine.

Therefore, attention is focused on the loading machine and factors that affect the overall performance of the production unit. Three complete mechanized production units are presented for analysis: A track section, a trackless section using battery-powered shuttle cars, and a trackless section using cable-reel shuttle cars. These particular sections were chosen for the following reasons: 1—The daily tonnage and mining conditions are approximately the same. 2—Production in each is 10 to 20 pct above the daily average. 3—The production characteristics and delays are average and typical. 4—They represent the manner in which the most of the nation's bituminous coal is produced.

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Discussion on this paper, TP 3140F, may be sent to AIME by Oct. 31, 1951. Manuscript, Feb. 22, 1951. St. Louis Meeting, February 1951.

Section A

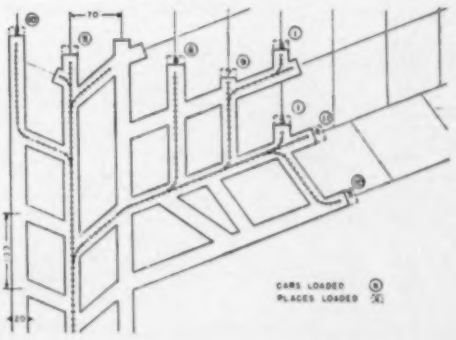
Fig. 1 is a layout for the track mining section showing the development to date, the projected plan and the cuts loaded on the shift studied. The seam mined averages 96 in. in thickness with a fireclay bottom and a roof of 10 in. of drawslate topped by sandstone. The mineability is considered good, and roof support is not a difficult problem. Two locomotives are used in the section to minimize the losses occurred in trip changing. The places are driven 20 ft wide, and the crosscuts are angled to permit fast tramming of the equipment.

Table I lists the equipment and labor that make up the section.

ANALYSIS

Production Characteristics: The average loading rate for eight loading machines studied of this type is 1.81 tons per min. This one at 2.78 is considerably above average.

Fig. 1—Section A track equipment.



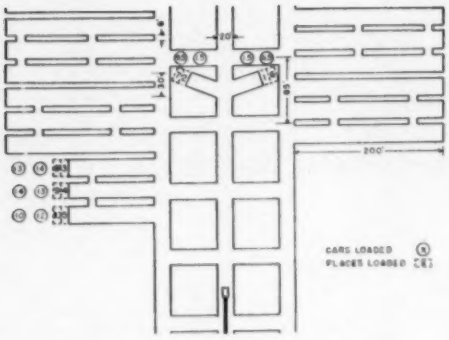


Fig. 2—Section B trackless equipment, battery shuttle cars.

Delay Characteristics: Mechanical delays accounted for 20.58 pct of the shift. Careful handling and preventative maintenance can reduce this item. Derails totaled 5.75 pct, a product of rough handling, poor track work, or operating technique. Inefficient deadwork and face preparation accounted for 6.15 pct of shift. Miscellaneous delays were low at 1.17 pct. Two places loaded yielded only one car each. Proper cleanup of these cuts on the initial loading cycle would have eliminated the tramming time involved.

Section B

Fig. 2 is a layout of a trackless mining section using battery-powered shuttle cars.

The seam mined averaged 72 in. in thickness.

The roof varies from 0 to 40 ft of friable shale and extensive timbering is necessary; the bottom is of hard fireclay. Mineability is considered fair with some difficulty in shooting caused by a middle band of rock.

Rooms are mined in sets of three on retreat approximately 24 ft wide on 30-ft centers. Entry pillars are drawn at the same time. No attempt is made to recover the room pillars.

Table II lists the equipment and personnel in the section.

ANALYSIS

Production Characteristics—The average loading rate for 23 loading machines studied of this type is 2.27 tons per min. At 1.96 tons per min this loader is below average, probably because of top rock and binder in the coal. Place change is about average for a crawler type loader. Travel distance of 624 ft per round trip is below the average of 850 ft for battery cars. Travel speed of 275 ft per min is less than the 326 ft per min average for battery cars, and discharge rate is average.

Delay Characteristics—(Loader) Inefficient deadwork and face preparation caused the largest delay, 10.80 pct; lack of coordination of main haulage with no empty mine cars, 4.38 pct; mechanical delays, 3.63 pct; and roof fall on loader, 1.96 pct. Miscellaneous delays were low at 1.92 pct.

Table I. Section A

Equipment: Loading machine, rated 3 tons per min; Universal cutting machine, bar 9 ft bottom cutting; drilling machine, 6 holes per cut; two 8-ton locomotives, 3 car trips; steel mine cars, rated 6.5 tons capacity.

Personnel: Section foreman, Loading machine operator, Loading machine helper, Cutting machine operator, Cutting machine helper, Driller, Shot firer, Timberman, two Trackmen, two Motormen, two Brakemen—**Total, 14.**

Operating Data	
Mining height, in.	96
Production, tons	326
Number of cars	53
Average car capacity, tons	6.15
Number of men	14
Production per man-shift, tons	23.2
Time in section, min	425

OPERATING CHARACTERISTICS	
Production Time, 66.35 Pct	
Average loading time per car	2.22
Average change car time per car	2.68
Total per car	4.90
Average place change time per place	2.81
Average trip change time	6.13
Average loading rate, tons per min	2.78
	281.00

TIME ELEMENTS OF SHIFT STUDIED	Min
Production Time, 66.35 Pct	
Loading time, 27.64 pct	117.45
Change car time, 33.42 pct	142.05
Place change time, 5.29 pct	22.50
	282.00
Delay Time, 33.65 Pct	
Tram chain failure (2), 12.92 pct	54.90
Loader derailment (2), 5.14 pct	21.85
Controller adjustment, 3.16 pct	13.45
Slate and lump handling, 2.70 pct	11.45
Lubrication, 2.44 pct	10.35
Locomotive cable failure, 2.06 pct	8.75
Track extension, 1.98 pct	8.40
Move junction box, 1.47 pct	6.25
Car derailment (3), 0.61 pct	2.60
Miscellaneous, 1.17 pct	5.00
	143.00
Total	425.00

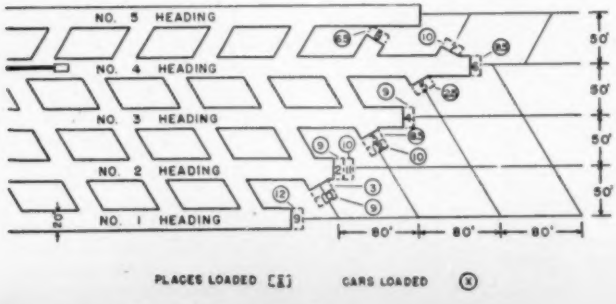


Fig. 3—Section C trackless equipment, cable shuttle cars.

Table II. Section B

Equipment: Crawler-mounted loading machine rated 5 tons per min, two battery-type shuttle cars rated 3.75 tons, Crawler-mounted cutting machine (9-ft bar, center cutting), Hand-held drill (seven holes per cut), 30-in. belt conveyor.

Personnel: Section foreman, Loading machine operator, Cutting machine operator, Cutting machine helper and driller, Shot firer, two Shuttle car drivers, two Timbermen, Supply and timberman, Boom operator—**Total, 11.**

Operating Data

Mining height, in.	72
Production, tons	332
Number of shuttle car loads	85
Average shuttle car capacity, tons	3.50
Number of men	11
Production per man shift, tons	30.2
Time in section, min	494

OPERATING CHARACTERISTICS

Loading Machine	Min
Production Time, 77.31 Pct	
Average loading time per car	1.79
Average change car time per car	1.31
Total per car	3.10
Average place change time per place	4.10
Average loading rate, tons	1.86
	335.50

Shuttle Cars	1	2
Trips	49	46
Travel speeds, ft per min	274	275
Average round trip, ft	618	624
Discharge time per trip, min	0.75	0.82
Discharge rate, tons per min	4.76	4.35

TIME ELEMENTS OF SHIFT STUDIED

Loading Machine	Min
Production Time, 77.31 Pct	
Loading time, 39.09 pct	169.65
Change car time, 28.78 pct	124.90
Place change time, 9.44 pct	40.95
	335.50
Delay Time, 22.69 Pct	
Move junction box (2), 6.15 pct	26.70
No empty mine cars, 4.38 pct	19.00
Loader cable, 3.36 pct	14.60
Slate and lump handling, 2.90 pct	12.60
Fall on loader, 1.96 pct	8.50
Timbering, 1.75 pct	7.60
Power failure, 0.27 pct	1.15
Miscellaneous—shuttle car, 0.99 pct	4.30
Miscellaneous, 0.93 pct	4.05
	98.50
Total	434.0

Shuttle Cars	1		2	
Time	Min	Pct	Min	Pct
Production	275.10	63.39	243.85	56.19
Loading	93.65	21.58	76.00	17.51
Travel	110.55	25.47	104.40	24.06
Discharge	36.85	8.49	37.70	8.69
Place change	34.05	7.85	25.75	5.93

Delays—Shuttle Car No. 1	Min
Delay Time, 36.61 Pct	
Waiting on other car, 14.11 pct	61.25
Mechanical delays—loader, 9.52 pct	41.30
No empty mine car, 3.95 pct	17.15
Slate and lump handling (loader), 3.08 pct	13.35
Fall on loader, 1.87 pct	8.10
Handling supplies, 1.73 pct	7.50
Belt stoppages, 0.87 pct	3.80
Miscellaneous, 1.48 pct	6.45
	158.90

Delays—Shuttle Car No. 2	Min
Delay Time, 43.81 Pct	
Mechanical delays and supply handling, 14.86 pct	64.50
Waiting on other car, 12.80 pct	55.55
No empty mine cars, 5.52 pct	23.95
Mechanical delays—loader, 4.30 pct	18.65
Belt stoppage, 2.00 pct	8.70
Fall on loader, 1.96 pct	8.50
Slate and lump handling (loader), 1.56 pct	6.85
Miscellaneous, 0.79 pct	3.45
	190.15

Table III. Section C

Equipment: Crawler-mounted loading machine rated 5 tons per min, two cable-reel shuttle cars rated 4 tons, Crawler-mounted cutting machine (8½-ft bar, bottom cutting), Crawler-mounted drilling machine, 30-in belt conveyor, Elevating conveyor (belt feeder).

Personnel: Section foreman, Loading machine operator, Loading machine helper, Cutting machine operator, Cutting machine helper, Driller, Shot firer, two Shuttle car operators, Boom operator, Ventilation and water man, Rock duster, three Timbermen—**Total, 15.**

Operating Data: Mining height, 66 in.; Production, 343 tons; Number of shuttle car loads, 96; Average shuttle car capacity, 3.5 tons; Number of men, 15; Production per man-shift, 22.8 tons; Time in section, 385 min.

OPERATING CHARACTERISTICS

Loading Machine	Min
Production Time, 76.06 Pct	
Average loading time per car	1.37
Average change car time per car	1.21
Total per car	2.58
Average place change time per place	3.33
Average loading rate, tons	2.35
	292.80

Shuttle Cars	1	2
Trips	54	44
Travel speeds, ft per min	290	283
Average round trip, ft	720	720
Discharge time per trip, min	0.70	0.68
Discharge rate, tons per min	5.00	5.26

TIME ELEMENTS OF SHIFT STUDIED

Loading Machine	Min
Production Time, 76.06 Pct	
Loading time, 34.95 pct	134.55
Change car time, 30.73 pct	118.30
Place change, 10.38 pct	39.95
	292.80
Delay Time, 23.94 Pct	
Weld discharge elevator, 4.68 pct	18.00
No empty mine cars, 2.89 pct	11.15
Cable failure, shuttle car, 2.52 pct	9.70
Shoot adjoining place, 2.36 pct	9.10
Tramming delays, 1.77 pct	6.80
Ventilation, 1.50 pct	5.80
Slate and lump handling, 1.26 pct	4.85
Belt stoppages, 0.88 pct	3.40
Lubricate loader, 0.60 pct	2.30
Reset timber, 0.49 pct	1.90
Miscellaneous shuttle car, 2.52 pct	9.70
Miscellaneous—loader, 2.47 pct	9.50
	92.20
Total	385.00

Shuttle Cars	1		2	
Time	Min	Pct	Min	Pct
Production	283.85	73.75	194.20	50.44
Loading	76.00	19.74	58.70	15.25
Travel	138.60	36.00	103.00	9.35
Discharge	38.00	9.87	29.80	7.74
Place change	31.25	8.14	2.70	0.70

Delays—Shuttle Car No. 1	Min
Delay Time, 26.25 Pct	
Cable failures, 2, 4.52 pct	17.40
Waiting for other car, 4.31 pct	16.60
Weld discharge elevator, 4.14 pct	15.95
No empty mine cars, 2.83 pct	10.90
Shoot place, 2.37 pct	9.10
Belt stoppages, 2.15 pct	8.30
Slate and lump handling, 0.72 pct	2.75
Wait to travel, 0.66 pct	2.55
Reset timber, 0.48 pct	1.85
Handling supplies, 0.13 pct	0.50
Lubricate loader, 0.10 pct	0.40
Miscellaneous, 3.83 pct	14.75
	101.05

Delays—Shuttle Car No. 2	Min
Delay Time, 46.56 Pct	
Handling supplies, 25.51 pct	98.20
Waiting for other car, 7.56 pct	29.10
Weld discharge elevator, 4.87 pct	18.75
No empty mine cars, 3.41 pct	13.15
Other car cable failure, 2.64 pct	10.15
Belt stoppages, 1.32 pct	5.10
Ventilation, 1.08 pct	4.15
Slate and lump handling, 0.55 pct	2.10
Lubricate loader, 0.49 pct	1.90
Miscellaneous, 2.13 pct	8.20
	190.80

(Shuttle Cars) The largest delay was waiting at standby positions for the other car to clear, 14.11 pct and 12.80 pct. Handling supplies accounts for 1.73 pct and 14.86 pct, a portion of which was a controller delay. No empty mine cars accounted for 3.95 pct and 5.25 pct. Belt stoppages caused 2.00 pct and 0.87 pct. Miscellaneous delays were low at 1.48 pct and 0.79 pct. The remaining delays were directly accountable to loader stoppages. Two places had to be cleaned yielding only 1½ cars each. Proper cleanup initially would have prevented needless tramming time. The position of the shuttle car discharge point caused a change-car time at the belt also. Side loading can eliminate this possible source of delay. With established loading rate, discharge rate, and travel speed, change car time becomes a function of distance and standby points. Right of way, although universally given to the loaded cars, should be given to the empty cars in this case.

Section C

Fig. 3 is a layout of the trackless mining section using cable-reel shuttle cars. The seam mined averages 66 in. in thickness. The roof averages several inches of draw slate topped by hand slate; the bottom is hard fireclay. Mineability is considered relatively good. Considerable timbering is necessary. Five places 20 ft wide are driven on 50-ft centers. Crosscuts are angled at 60°.

Table III lists the equipment and personnel in the section.

ANALYSIS

Production Characteristics—The average loading rate for 29 loading machines of this type studied is 1.64 tons per min. This loader with an average of 2.55 tons per min is well above average. Place change is about average, long trams being balanced by very short ones. Travel distances of 720 ft per round trip are longer than the average of 680 ft for cable reel cars. Travel speeds of 290 ft per min are higher than an average of 275 ft per min for cable reel cars. Discharge rate at 5 tons per min is higher than average for cable reel car at 4.34 tons per min.

Delay Characteristics—(Loader) Mechanical delays accounted for 7.80 pct of the shift, the largest portion being a welding job on the elevating belt feeder. Poor coordination of section tramming and cable handling accounted for 1.77 pct of the face time. Lack of empty cars and belt stoppages caused by trip changes took 3.77 pct. Careless driving and miscellaneous shuttle car delays accounted for 3.01 pct. Miscellaneous delays to the loader was 2.47 pct, rather a high figure.

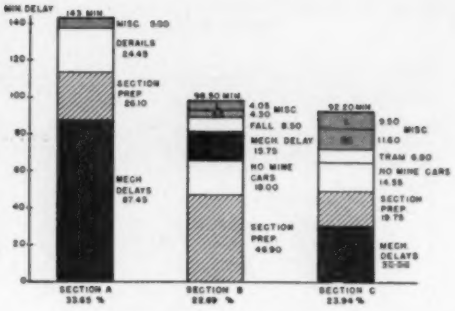


Fig. 5—Grouped loading delays in minutes.

Shuttle Cars: Handling supplies took 25.51 pct of the shift for one car, an abnormal amount. Wait at standby positions for other car was 4.31 pct and 7.56 pct. Lack of empty mine cars was 2.83 pct and halting shuttle car movement, 3.41 pct. Belt stoppages caused by changing mine car trips accounted for 2.16 pct and 5.10 pct. Two cable failures of one car took 4.52 pct while the other car was unable to travel for 2.64 pct. One car was delayed for 0.48 pct by careless driving or timbering that resulted in the need to replace a knocked out post under a header. Welding of the discharge elevating feeder was responsible for 4.14 pct and 4.87 pct. Miscellaneous delays were high at 3.83 pct and 2.13 pct, partially attributed to a new driver.

Supplies must be handled, and it is a characteristic of shuttle car belt sections that one shuttle car loses time to handle them. Evaluation of this time might indicate that a supply jeep or a timbering machine with trailer could be justified to eliminate the lost shuttle car time. Cable failures occurred at the discharge station, delaying both cars. Provision of two belt loading stations would have prevented the delay to one of the shuttle cars.

Section Comparisons: The relative performance of the loading machine with a shift average and a shift maximum is compared in Fig. 4. The delays according to groups and the actual time lost are given in Fig. 5. Fig. 6 shows the components of shift in percentage.

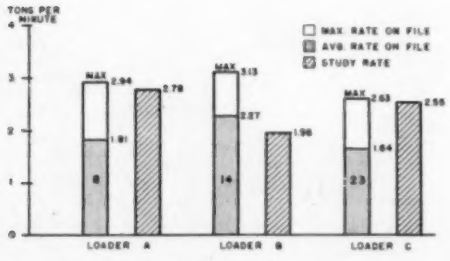


Fig. 4—Loading machine performance.

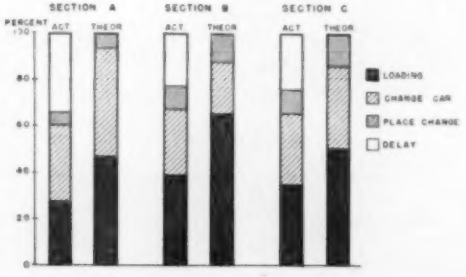


Fig. 6—Components of shift in percentage.

Theoretical Characteristics

For any given set of conditions it is desirable to know the maximum production possible. If this theoretical performance figure is developed, equipment ratings in one mine can be compared with another

It is obvious that a mathematical relationship exists between all the time elements making up an operation. For one shuttle car, the sum of travel empty, loading, travel loaded and discharging constitutes a productive cycle. This same principle can be applied to the loading machine using a single place as a basic operation. Equating the time elements for a single place to the productive effort:

Loading time per place + Change car time per place + Place change time = Productive effort per place.

The values for this equation are developed as follows: *Loading*—The average loading rate in minutes per car multiplied by the number of cars per place. *Change Car*—The average change car rate in minutes per car multiplied by the number of cars and modified from the average as follows:

One change car time is eliminated, assuming the car should be in position when the loader reaches the face in the new place.

A. The average used is for a full cut of nine cars including two trip changes.

B. Two cars are considered in operation for the full shift. Standby position at room neck is changed to the nearest breakthrough. The average is recalculated to obtain this.

C. Two cars are considered in operation for the full shift. The average is derived from the portion of the shift that they were in continuous operation.

Place Change—The average value for the study in minutes per place change.

Maximum Theoretical Production

Loading (min per car) × N (cars per place) + Change car (min per car) × (N-1) + Place change (min per place) = Productive effort (min per place)

Table IV. Theoretical Performance Rating

	Section		
	A	B	C
Cars per cut	9	12	9
Loading time per car, min	2.23	1.79	1.97
Change car time per car, min	2.42	0.65	1.06
Place change avg, min	2.81	4.10	3.33
Cycle time per cut, min	42.15	32.73	24.30
Cuts per 420 min shift	9.96	12.83	17.28
Cars per shift	89.64	153.96	155.52
Tons per car	6.15	3.50	3.80
Tons per shift	551.3	538.9	544.3
Tons per manshift	39.4	49.0	36.3

From a time basis this is developed into production:

Places per shift × tons per place = tons per shift.

Table IV lists the theoretical performance possible for each of the sections analyzed for a common shift of 420 min.

The maximum theoretical production could be used as a standard; the product of careful study to determine the actual components of productive effort under existing conditions.

It should be emphasized that the preparation of the coal and the loading and tramming rate of the loading machines, governed partially by operating skill, greatly influence the production effort.

Production and Shift Ratings

From the theoretical calculations and obtained data it is possible to derive a production rating and a shift rating. The production rating is the comparison of the production with the theoretical characteristics and the actual production with the present characteristics. The shift rating is the comparison of the theoretical production for the full shift and the actual production for that shift.

Table V gives the calculations for these ratings while Figs. 7 to 10 are graphic comparisons.

The elimination of delays and increased production ratings cannot be emphasized too strongly.

Section A: The productive rating is 88.1 pct. Clean-up of several places yielding less than the average tonnage per cut contributes to this rating.

Table V. Production and Shift Ratings

	SECTION A			SECTION B			SECTION C		
	CHARACTERISTICS			CHARACTERISTICS			CHARACTERISTICS		
	PRESENT		THEOR.	PRESENT		THEOR.	PRESENT		THEOR.
Existing Full Shift	491.3		557.9	429.4		556.9	450.9		498.9
Effort, pct		88.35			77.31			78.08	
Production for present effort	326.		370.1	332.		430.5	343.		379.5
Productive rating, pct	326. / 370.1	=	88.08	332. / 430.5	=	77.12	343. / 379.5	=	90.38
Shift rating, pct	326. / 557.9	=	58.44	332. / 556.9	=	59.62	343. / 498.9	=	68.75
Efficiency loss, pct	11.92			22.88			9.62		
Delay loss, pct	491.3-326 / 557.9	=	29.64	429.4-332 / 556.9	=	17.50	450.9-343 / 498.9	=	21.63

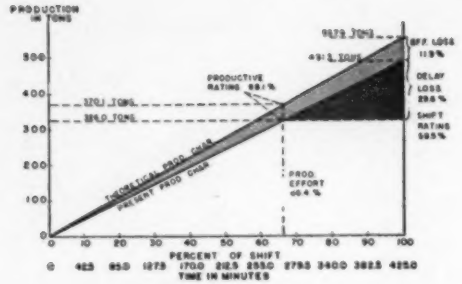


Fig. 7—Section A production characteristics.

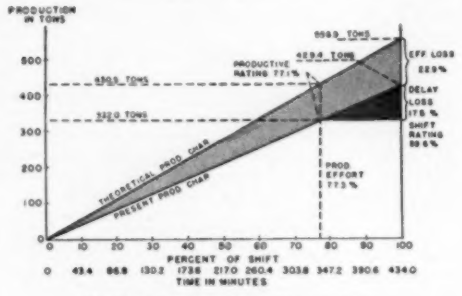


Fig. 8—Section B production characteristics.

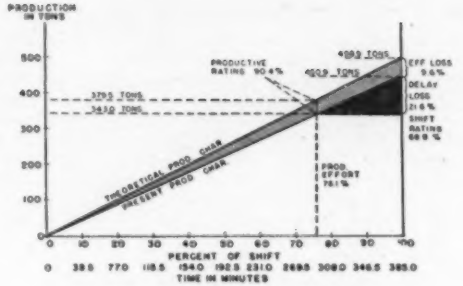


Fig. 9—Section C production characteristics.

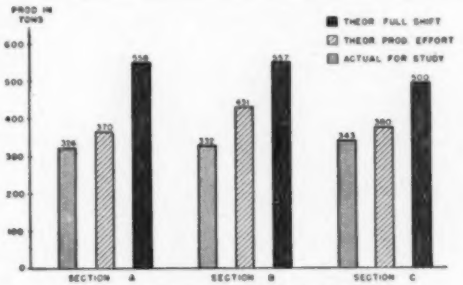


Fig. 10—Comparison of theoretical and actual production.

The shift rating is 58.5 pct with efficiency loss accounting for 11.9 pct and delay loss accounting for 29.6 pct.

Section B: The productive rating is 77.1 pct. Breakdown of one car or handling supplies by one car and the inefficient standby position in addition to revisiting cuts for cleanup accounts for this low percentage. The shift rating is 59.6 pct with efficiency loss accounting for 22.9 pct and delay loss accounting for 17.5 pct.

Section C: The production rating is 90.4 pct. Handling supplies and breakdown of one car not affecting the operation of the other and cleaning of partially loaded places account for this rating. The shift rating is 68.8 pct with efficiency loss accounting for 9.6 pct and delay loss accounting for 21.6 pct.

Continuous Mining

The more important deficiencies encountered in the use of continuous mining machines are well known, but these are being corrected and improved. The present machines produce a product that consists of a large proportion of small sizes and, as in operations where spraying is mandatory, the moisture content of the product is higher. The small sizes place an additional load on the cleaning plant, and where moisture and size must meet rigid specifications, the problem becomes more difficult.

Costly capital expenditures and changes of market for the product must be carefully considered before entering into continuous mining. With conventional mining systems, minor changes in face preparation can often be made to alter the product to meet market specifications. With continuous mining systems, flexibility of product is limited.

Fig. 11 shows the labor productive comparison of conventional mining sections and continuous mining sections in the same mines operating in the central Pennsylvania area.

The information in Fig. 11 can be misleading if all factors are not considered. The continuous mining machines are restricted by seam conditions, and the increased labor productivity is not always realized as profit because of the change in realization from the marketed product.

It is believed that conventional mechanized mining systems will be employed successfully for a considerable time. Modernization of mines can be done efficiently without converting to continuous mining machines. However, the mine operator should look forward to the day when he may want to convert his operation to continuous mining and should consider major capital expenditures and improvements with the thought of their future relationship with continuous mining.

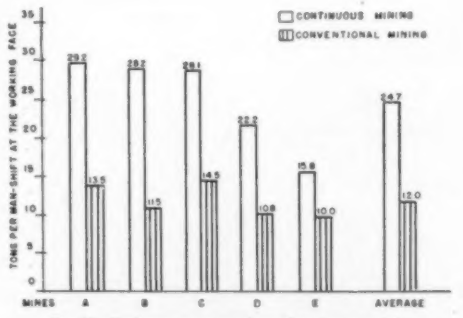


Fig. 11—Performance comparison of equipment working in the same mines, low volatile bituminous coal in central Pennsylvania.

Coal Transport Via Pipe Line Claimed Feasible

Moving coal via pipe line is a project proposed by the U. S. Bureau of Mines. A pipe line 100 miles long capable of transporting 5000 tons of coal a day with water could be built for about $10 million. The cost of moving the coal 100 miles would be between $1.28 and $2.01 a ton.

R. W. Dougherty, Louisiana, Mo., industrial engineer for the Bureau, released construction and operating cost estimates for the same length pipe line moving up to 36,000 tons per day. While construction costs would rise for the larger capacity lines, transportation costs would go down. It is estimated that 36,000 tons a day could be moved for 38 to 95¢ per ton.

The method has been used successfully for short hauls, the latest development in the field being an announcement by Pittsburgh Consolidation Coal Co., Pittsburgh, of plans to build a full-scale demonstration pipe line in Ohio for pumping finely ground coal mixed with water for a distance of 3 miles.

A 5000 ton a day, 100-mile line would cost about $10 million; but a 36,000 ton a day, 100-mile line would cost $25 million. The 36,000 ton a day, 100-mile line would require from 1½ to 2 million gal of water daily.

National Lead Buys Interest in Nicaro Nickel

National Lead Co. is acquiring a substantial interest in Nickel Processing Corp., which will operate the former Nicaro Nickel Co. property in Cuba. The mine and reduction plant will be operated under contract with the General Services Admin. Sharing ownership of Nickel Processing Corp. are Tin Processing Corp., controlled by the Billiton interests and Cuban nationals. Rehabilitation work has already started with a force of about 800. The objective is to get production under way as soon as possible, using a total production force of about 1500, mostly Cubans.

New Process Yields Tar And Power From Lignite

After nearly two years of research, the Bureau of Mines today unveiled a new process that offers promise of making the West's immense reserves of lignite and other low-rank noncoking coals a major source of both low-cost electric power and coal tar products.

Soon to be applied commercially in providing fuel for power generation at a new aluminum smelting plant 60 miles south of Waco, Texas, the process was developed in the Bureau's coal branch laboratories

(Continued on page 810)

Mining News Fronts

- Vanadium Corp. of America's Durango mill in Colorado will be increased in capacity, with the approval of AEC. Increases in ore reserves from purchase and lease of claims during the past year will permit utilization of greater amounts of vanadium and uranium ores.
- GOP Antimony Corp. has been rehabilitated and placed into operation by American Graphite and Metals Co., near Omak, Wash. The concentrator, idle for two years, has been processing antimony since July. Shipments of flotation concentrates go to Hummell Chemical Co., New York, and paint producers in the East.
- Nancy Lee Mines, Inc., has opened a 300 ft drift showing silver-lead-copper-gold ore in a 9 ft vein at its property near Superior, Mont. Raises are being started, and six faces will be advanced simultaneously.
- A $1,875,000 loan from the Export-Import bank will provide funds for construction and working capital of a new sulphur plant to be built at San Cristobal, Mex., by Mexican Gulf Sulphur Co.
- The petroleum industry will up sulphur production by 190,000 tons a year, according to Deputy Petroleum Administrator, Bruce K. Brown. Acid recovery and sulphur extraction operations, along with recovery from spent acids and sludges and recovery of hydrogen sulphide from petroleum operations will account for the increase.
- Monsanto Chemical Co. will build a large elemental phosphorus plant at Soda Springs, Idaho. Power for this plant will be from Utah Power & Light Co., and John E. Gurben, of Everett, Mass., is plant manager and in charge of construction. Phosphate beds are about 14 miles from the present planned furnace site, and material will be open pit mined by Morrison-Knudsen, Boise, Idaho, under contract. Morrison-Knudson is also constructing the plant.
- Kennametal, Inc., is planning a $150,000 mining tool plant at Bedford, Pa. The new plant will release space at Latrobe, Pa. for stepping up production of armor-piercing projectiles. One $4,200,000 order is underway, and another has been received for work totaling $3 million.
- $100,000 has been invested by Haile Mines, Inc., New York, in a tungsten hunt on Iron Mountain, 10 miles east of Winston, New Mexico. Early reports indicate richest samples tested 300 lb of tungsten to the ton.
- Approval and signing of 45 new contracts for mineral exploration projects by the Defense Minerals Administration brings the total of such contracts to 93. These 93 contracts call for expenditures of $6,326,919 by private industry and Government, with the Government contribution totaling $3,695,864 or 58 pct. There are 17 minerals represented in the 93 projects.
- A new high speed mine hoist is being installed at Alan Wood Steel Co.'s Scrub Oaks mine, Dover, N. J. The hoist is designed to lift 250 tons of ore an hr up a 3800 ft shaft. Operating at a rope speed of 2315 fpm, the hoist will deliver a 9-ton load every 2 min. The hoist will use two skip buckets, 9-ton capacity each, built by Nordberg Mfg. Co., Milwaukee; and GE will supply electrical equipment. The new hoist will boost production of ore to 2000 ton per 8-hr shift.
- "Several hundred thousand dollars" will be spent in exploration and development of Bradley Mining Co.'s Idaho mining properties. The company has mapped three tungsten projects.
- A 15 million metric ton iron ore deposit in Michoacan, Mexico, has been discovered according to the Mexican National Institute for Investigation of Mineral Resources. The ore contains 67 pct iron and the deposit is at Cerro del Cubero.
- $1 million plus is being spent by Giant Yellowknife Gold Mines for expansion and construction. The project includes doubling the size of the present mill, considerable underground work including a new shaft, and two electrical substations and additional electric heating boilers.
- Bethlehem Steel Co. is identified with the possible development of iron ore in Hastings Co., Ontario. The deposit is reported buried under limestone.
- St. Joseph Lead Co. has scheduled the expenditure of $15 million for expansion of facilities through 1953. $6 million will be spent for the new Lead Belt mining properties in Washington County and at Hayden Creek, $4 million for the new zinc furnace and modernization program at the Herculaneum lead smelter, $3 million for increased zinc production facilities at Balmat and Edwards, and $2 million for an additional electrothermic zinc furnace and related plant at Josephtown.

and pilot plants at the Denver Federal Center under a cooperative agreement with the Texas Power and Light Co., J. H. East, Jr., regional director of the Bureau, announced.

Major products of the process, a variation of low-temperature carbonization, are a high heating value char ideal for power plant use and crude coal tar, which is the source of a myriad of byproducts, including wood preservatives, plastics, explosives, drugs, and dyes, he said.

V. F. Parry, chief of the Denver laboratories and the man under whose supervision the process was developed, said: "It is applicable to any coal of lesser rank than high volatile bituminous B, a bracket that encompasses 90 pct of all western coals.

"If merely an average western coal is used, the value of the tar recovered—at least 8 to 10¢ per gal—alone is equal to the cost of the raw coal," Parry said. "The more favorable coals will yield as much as 45 to 55 gallons of tar oil per ton. Indicated processing costs are relatively nominal, and the char remaining thus can compete with natural gas as a fuel.

"According to our calculations, based on pilot plant results, profits from the 14 gallons of tar recovered from a ton of Milam County, Texas, lignite will enable even this fuel to compete with natural gas selling at 5 to 8 cents a thousand cubic feet," he stated.

Alcoa has selected Milam County, Texas, as the site of a new aluminum smelting plant that will have a capacity of 85,000 tons of metal annually with initial production scheduled for the fall of 1952. When in full operation, the plant will employ about 1000 persons. The large amounts of electricity required by the new plant will be generated by steam-driven equipment using as fuel lignite processed by the Bureau's carbonization method. Power generating facilities will be built and operated for Alcoa by the Texas Power and Light Company.

New Method For Setting Diamonds in Drill Bits

Engineers of the U. S. Bureau of Mines Mt. Weather station are conducting tests designed to improve the efficiency of diamond drills used to bore through hard rock and ore deposits. The techniques developed by generations of commercial gem workers are being applied in reverse in the experiments.

Diamonds do not have uniform hardness, so gem cutters take advantage of this and speed up the work by cutting and polishing the softer directions and planes of a gem. Conversely, the Bureau of Mines believes that more footage can be drilled and the bits will last longer if the harder parts of the diamond are identified and each diamond is set in the drill bit so its hardest part will do the cutting of rock and ore. In bort bits the diamonds normally are set into the bit in random fashion without regard to the hard or soft faces of the individual diamonds.

Although the Mt. Weather research in specialized setting of the diamonds is showing promising results, engineers emphasize that the investigation still is in its infancy. Additional experiments, extending over several years, are planned to gain more conclusive evidence.

International Allocation Of Strategic Metals

International allocation of three of the world's critical raw materials sulphur, tungsten, and molybdenum, will become effective beginning with the third quarter of this year. Scheduled for consideration by the 25 nations participating in the International Materials Conference which worked out the allocation program are plans for allocating copper, zinc, cotton, manganese, nickel, cobalt, wool, and pulp and paper products.

Under the agreement the United States will receive about 70 pct of the free world's sulphur during the third quarter of this year or 1,050,000 tons, 44.8 pct of the tungsten, and 77.8 pct of the molybdenum or a total of 3420 tons. Prices for tungsten were established at $55 per ton minimum and $65 maximum.

Mining Priority Aid

The National Production Authority issued a special maintenance, repair, and operating order for the mining industry on Aug. 6 which permits the Defense Minerals Administration to give special priority assistance in obtaining the machinery and supplies necessary to expan[illegible] basic mineral output at home and abroad. Officials indicated that the order, in effect will permit DMA to have virtually complete control over channelling scarce equipment to mines so that it can be selective in its allocations.

Hanna Puts New Coal Cleaning Plant Into Operation at Cadiz, Ohio

The Hanna Coal Co. Div., of Pittsburgh Consolidation Coal Co., this past month put into operation its Georgetown Preparation Plant, the largest coal cleaning plant in the industry. Costing more than $5 million, exclusive of rail and weighing facilities, it is the latest completed project in Pittsburgh Consolidation's modernization program. In the past five years, the company has spent $80 million.

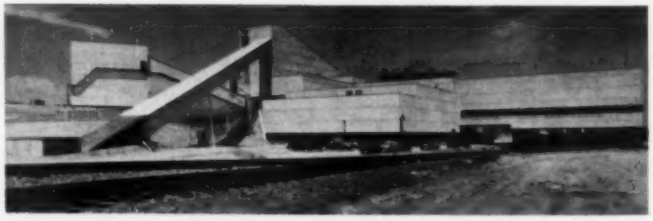
The coal preparation plant is located 2 miles southeast of Cadiz, Ohio, and has a capacity of 1500 tons of raw coal input per hr. It will produce 1275 tons of clean product per hour. Tests on first runs show that coal is upgraded in heat value from a range of 10,000 to 12,000 Btu's per lb for raw coal to about 13,000 Btu's per lb for clean product.

Raw coal is passed over shaker screens and classified. Small sizes, ¼-in. screen product, are cleaned by 30 Deister vibrating tables, handling 300 tons per hr. Drying is through settling tanks, centrifugal dryers, and heated flash dryers, reducing the moisture content to about 2.5 pct.

Intermediate sizes, ¼ to 1.5 in. screen size, pass through a Chance cone and flotation cleaning process with a capacity of 500 tons per hr. Small sizes are dried to 2 pct or less moisture in a new type of heated conveyor drive.

Large sizes, 1.5 in. to 7 in. screen size, are washed in two McNally Baum jigs of special design and having a capacity of 700 tons per hr. Jigs are used here because in addition to cleaning they make an extra separation of "middlings". This middlings material is coal with bands of impurities. By crushing and resizing, the coal is recovered by recirculating in other cleaning circuits.

A combination of storage bins and a mixing conveyor makes possible blending and loading various sizes or combinations of sizes on any of five railroad tracks. A car can be loaded every 2 min.



Hanna's Georgetown preparation plant, showing the layout and elevation. Loading facilities are at the right, and the raw coal conveyor and refuse loading bin at left.

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aime NEWS

AIME-ASME Joint Fuels Conference To Feature Panel Discussions on Coal Preparation

The 14th Joint Fuels Conference sponsored by the Coal Div., AIME and the Fuels Div., ASME will feature three panel discussions and one general session on the technology of coal preparation and use as a fuel. The meeting will be held at the Hotel Roanoke, Roanoke, Va., Oct. 11 and 12. The first panel discussion will be devoted to the equipment and practice of coal thickening and desliming. In this symposium J. P. Blair, Heyl & Patterson, will discuss, "Operational Data for Cyclone Thickener Operations;" D. A. Dahlstrom, Northwestern University, will talk on, "Low Cost Industrial Desliming of Fine Solids;" K. Prins, Prins & Associates, will discuss, "Slurry Thickening with the Stream Cleaner;" and H. R. Hagen of Philadelphia & Reading Coal & Iron Co. will speak on, "Operational Data for the Locust Summit Thickener." Others participating in the discussion will be John Griffen, McNally-Pittsburgh Co.; E. B. Nelson, Tennessee Coal, Iron & Railroad Co.; and Victor Phillips, Eastern Gas & Fuel Associates.

The second panel discussion will be on the subject of "Engineering Service in the Coal Industry." Speaking on this topic will be U. B. Yeager, Island Creek Coal Sales Co.; George P. Cooper, Empire-Hanna Corp.; Max A. Tuttle, Enos Coal Mining Co.; E. J. Kerr, Baltimore & Ohio Railroad.

The third panel discussion will be on "Fuel and Equipment Consulting Service for Small Steam Generating Plants." Speaking on this subject, A. R. Miller, General Foods Corp., will present the viewpoint of the small plant owner; E. C. Payne, Pittsburgh Consolidation Coal Co., will present the point of view of the coal producer; H. C. Carroll, Commercial Engineering and Testing Co., will discuss the viewpoint of the consulting engineer; E. C. Webb, Iron Fireman Corp., will speak for the equipment manufacturer; and W. S. Major, Dravo Corp., will present the viewpoint of the construction contractor.

The fourth session will feature the following papers: "Determination of the Free Swelling Index of Coal Employing Electric Furnaces and Heaters," E. Swartzman and G. C. Behnke, Canadian Bureau of Mines; "Air Pollution from Gob Piles," Henry F. Hebley, Pittsburgh-Consolidation Coal Co.; "Changing Characteristics of Storage Coal," T. F. Downing, Jr., Philadelphia Electric Co.; "Filter Cake Size-Consist and Moisture Relationships," O. R. Lyons, Republic Steel Corp.

On Oct. 11 at the all-conference luncheon, R. H. Smith, president, Norfolk & Western Railway Co. will be the guest speaker. At the banquet, on this same date, Walter S. Newman, president of the Virginia Polytechnic Institute, will be the guest speaker. At this dinner, the Percy Nicholls Award for 1951 will be presented to Alfred R. Mumford.

Ladies are cordially invited to attend the conference and plans for their entertainment include attendance at the all-conference luncheon and banquet, as well as a bridge-canasta party and tea on Oct. 11. On Oct. 12, there will be a visit to the Natural Bridge of Virginia, one of the outstanding natural wonders of the North American continent, luncheon at the Natural Bridge Hotel, and a visit to nearby historic Lexington including the campuses of the Virginia Military Institute, and Washington and Lee University.

The Roanoke Hotel, one of the best known hostelries of the South, patterned on the style of an English inn, with its comfortable rooms, fine appointments, spacious convention facilities, and excellent cuisine affords an ideal location for the meeting. Those attending are certain to have a pleasant stay at the Roanoke. For those who like to mix golf with business, the facilities of the Roanoke Country Club are available. At this season the Virginia countryside is most beautiful. Make your reservation in Roanoke early. Other hotels available include the Patrick Henry and the Ponce de Leon.

AIME Board Rejects Proposed MED Tax Resolution

At the June meeting of the AIME Board of Directors extended discussion was given to a proposed resolution of the Board on the subject of mineral taxation. The resolution was drafted by the Taxation Committee of the MED under the chairmanship of M. D. Harbaugh. It was presented by Richard J. Lund, Chairman of the Mineral Economics Div., and supported by M. D. Harbaugh, Maurice Peloubet, and Russell Bennett. The resolution developed from a session on taxation, tariffs, and subsidies at the St. Louis Annual Meeting last February, and was intended as a test of how far the Board wished to go as a result of the revision in its declared policy on controversial matters, as adopted at the Board meeting on June 22, 1950.

The resolution stated that the Officers and Directors of the AIME urge modification of the Federal tax laws and regulations by appropriate action to effectuate nine proposals, which may be summarized as follows: (1) New mineral enterprises should not be required to pay income taxes until the initial investment is recovered. (2) Percentage depletion allowances should be adequate to permit the tax-free return of the total "capital value" represented by the minerals produced. (3) Every distribution made by a mineral producer should be considered in part as tax-free depletion. (4) All development expenditures after discovery should be recognized as deductible operating expense. (5) Losses of loss years should be fully deductible against income of profitable years in determining taxable income. (6) Losses from investments in unprofitable mineral ventures should be deductible from current income for

corporations, partnerships, and individuals alike. (7) Depreciation allowances should be more liberal, with greater deductions in years of greater income. (8) Adequate foreign tax credit should be allowed to investors in foreign mining enterprises. (9) The above proposals should be applied to enterprises recovering strategic materials by methods not previously commercially developed.

Discussion disclosed a generally adverse opinion towards passage of the proposed resolution. There was little question that establishment of a more favorable tax climate for the mining industry was desirable, and that the proposals were suited to this end. The chief objection seemed to be that as a matter of principle the Board should not go on record as supporting a resolution of this type. It was felt that, were this adopted, many other resolutions of similar type would also be presented, and that the prestige of the Institute would be adversely affected. It was brought out that other organizations speak to advantage for the mineral industry on such problems, so the need for passage of the proposed resolution was not so acute; it would merely bolster the argument of others. More properly, the AIME should act as a forum on such matters, as it had at the St. Louis meeting, without official Board action. Thus it would stimulate individual action by its members after aiding in the development of intelligent thought.

New Mexico Geological Society Announces October Field Conference

The second field conference of the New Mexico Geological Society will be held Oct. 12 to 14 along the south and west flanks of the San Juan Basin of northwestern New Mexico. Participants should register in Albuquerque, N. Mex., the afternoon and evening of Oct. 11, 1951. All geologists, students, and others interested in the geology of northwestern New Mexico are invited.

A guidebook is being prepared under the editorship of Clay T. Smith of the New Mexico Institute of Mining and Technology which will contain articles on the structure and stratigraphy of the south and west sides of the San Juan Basin. Additional chapters on ground water, petroleum history and statistics, and mineral resources are planned as well as detailed road logs, and maps and sections pertinent to the route.

All inquiries concerning the conference should be addressed to Eugene Callaghan, secretary-treasurer, New Mexico Geological Society, Campus Station, Socorro, N. Mex.

Peirce Guest of Montana Section

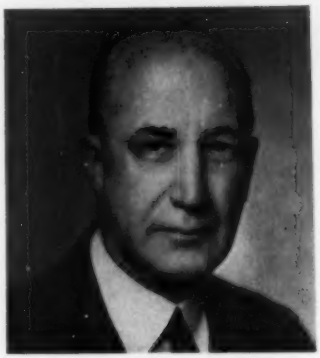
The Montana Section recently had AIME President W. M. Peirce as guest of honor at Butte on June 28. Mr. Peirce spoke informally at a discussion prior to a luncheon on Institute affairs, what the organization is doing, and what it proposes to do. Kuno Doerr, Jr., Chairman of the Montana section who was toastmaster; Roy O'Brien, Western Secretary, AIME; C. H. Steele, Vice-Chairman of the section; F. W. Strandberg, Secretary-Treasurer; M. C. Messner, member of the Executive Committee; E. S. McGlone, chairman adviser of mining; and M. H. Gidel, chairman adviser on geology were among those present.

Speaking of zinc operations, Mr. Peirce said "zinc in general is experiencing the same trend as other nonferrous metals. Growth of the population of the nation, and increase in per capita use has resulted in a strong market and has stimulated search for new orebodies."

New Book for Junior Members

A new book is to be made available to new Junior Members, as a gift of the Seeley W. Mudd Memorial Fund, later in the year. It is "*The Formation of Mineral Deposits*," by Alan M. Bateman, which is being published by John Wiley & Sons. The Fund Committee has purchased 1000 copies, and the volume will be included in the list for Junior Members as soon as published. The price of the book to the public will be $5.50.

E. G. Bailey, Ex-President ASME, Selected John Fritz Medal Winner



ERVIN GEORGE BAILEY

Ervin George Bailey, past president of the American Society of Mechanical Engineers and vice-president of Babcock & Wilcox Co., was selected by the John Fritz Medal Board of Award to receive the 1952 John Fritz Medal and Certificate "for outstanding engineering achievements in the field of combustion and distinguished service to his fellows in advancing the engineering profession."

The John Fritz Medal was established in 1902 by friends of John Fritz on the occasion of his eightieth birthday to honor him for his great contributions in the manufacture of steel and in the advancement of industry generally. It is perpetuated by the four leading engineering professional societies, ASCE, AIME, ASME, AIEE as a joint honor for scientific or industrial achievement in any field of pure or applied science, without restriction on account of nationality or sex. Sponsored jointly by these four national professional societies, the award is often referred to as "the highest award in engineering."

Mr. Bailey has been granted nearly 100 patents involving improvements in efficiency and operation in fuel burning and steam generation. He assisted in the organization and was chairman of the Engineering Manpower Commission of the Engineers Joint Council and is one of the few American engineers who are honorary members of the Institution of Mechanical Engineers, London.

MGGD Adds Nominees

Supplementing Divisional nominations for officers in 1952 already announced, the Mining Subdivision of the Mining, Geology, and Geophysics Div. has named the following: E. D. Gardner, chairman; Tell Ertl, secretary; W. C. Lawson and Vinton H. Clarke, committeemen. The Geology Subdivision has named J. D. Forrester chairman, John H. Melvin secretary, and John S. Brown and Ralph Tuck committeemen.

Agricola Mailing Completed

All orders for the reprint of the Hoover translation of Agricola's "*De Re Metallica*" have now been filled. If any AIME members who ordered the volume have not received it, the Secretary's office should be immediately advised. The reprint sells for $10 net, with a 10 pct discount on orders for two or more copies. Approximately 200 copies remained in stock early in August. When these are gone, the book promises to be difficult to obtain.

Technical Program, Social Events, Sightseeing, and AS&R Plant Inspection Trip Highlight AIME Mexico City Meeting

All reports indicate great interest in the Fall Meeting of the AIME in Mexico City in the week beginning October 29 and an attendance which may range up to a thousand. The local committee, especially Alfredo Terrazas, Mexico Section Chairman, William G. Kane, Secretary, and H. F. Hurley have been working night and day on arrangements and they promise that the week will be a never-to-be-forgotten one for those who are there, and a matter for long-time regret for those who are absent. Aguirre's Guest Tours may have to double its staff to handle the AIME convention but it is familiar with large affairs and will handle the Rotary and Lions conventions to come, as it did the Shriners last year.

In view of the large attendance expected, the "package" prices quoted by Aguirre have been reduced by ten dollars. This price includes 7 days' lodging in four top hotels in Group III, twelve somewhat less luxurious hotels in Group II, and five slightly less expensive hotels in Group I. Also included in the package price are certain transportation facilities, a four-hour sightseeing trip in Mexico City, a spectacular gala exhibition of Mexican costumes, dances, and music; a special banquet and entertainment at the El Patio night club; and what promises to be an outstanding climax: a trip to Xochimilco and its floating gardens with a luncheon included. The over-all prices for all of these events, including 7 days' lodging in a double room, have been reduced to $56 per person in Group I hotels, $61 in Group II, and $71 in Group III. If a person cannot stay for the full 7 days, a rebate of $3.50 per day will be made in the case of Group I and II hotels, but no rebate is possible for the Group III hotels. Should a single room be desired, the package price per person will be $14 higher, with a rebate of $5.50 per day for less than 7-day occupancy.

For local members, and those who for other reasons may not wish to select one of the package prices, individual tickets will be available in limited number for the social events, the prices to be determined later to accord with the number sold. Advance orders for tickets are urgently requested so that adequate plans can be made by Aguirre.

Members of the AIME may also reserve their own hotel rooms if they wish, either through a local travel agency or writing to the hotel of their choice direct, but individual reservations are not recommended by our

(Continued on page 814)

Mr. William G. Kane
San Juan de Letran 9, Room 805
Mexico 1, D. F.

I expect to come to the Fall Meeting in Mexico City, and am interested in a (single) (double) room at the over-all double-room price per person, including social events but not hotel meals, of ($56), ($61), ($71). There will be ..... men and ..... ladies in my party. Expected date of arrival ..... ; departure ..... ; by (rail), (airplane), (automobile).

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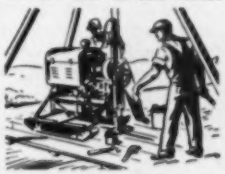

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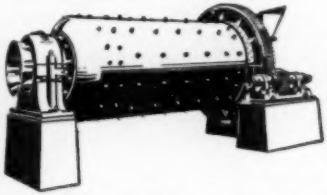
See our four-page insert in the Mining Catalogs

WHAT HAPPENS INSIDE A ROD MILL?

The answer to this controversial question is thoroughly covered by Hardinge in Bulletin 25-C-2 (just off the press) on the subject of rod mills, their proper field of application, and specifically—how Hardinge Rod Mills solve some of the usual problems.



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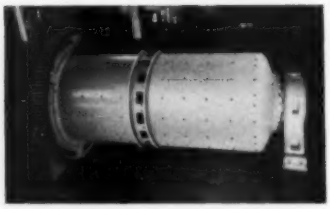

Hardinge Rod Mill with peripheral center discharge

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Mexico Section. An advance deposit is strongly urged in such cases, and even then occupancy of a room may be contingent on others checking out. Payment of the package price guarantees the availability of a room upon arrival. Those who have filled out the coupon in previous issues are not thereby guaranteed a room unless they have subsequently completed arrangements through Aguirre (Aguirre's Guest Tours, S.A., Cinco de Mayo 18, Mexico 1, D. F., Mexico.)

If you plan to travel to Mexico City by automobile, write AIME headquarters in New York for a free reprint of the June Atlantic article, "Mexico With a Car", and if you plan to enter by the road from Laredo ask also for the geological road log. If you plan to travel by rail or air, either direct or via Los Angeles where the Mining Congress and AIME Southern California Sections will have meetings the previous week, you are urged to compare the fare quoted in the USA with the price which Aguirre will be glad to quote you for the same accommodations. Certain economies may be possible through the purchase of tickets in Mexico. State exactly where and when you want to travel and how many of your family will accompany you. American Airlines will carry your family for half price on Mondays, Tuesdays, and Wednesdays.

The trip to Taxco, including the AS&R operations there, with a complimentary luncheon, is the outstanding event for Friday. The price of this will be $5.25 (not included in the package price). Arrangements have been made also for a trip on Friday to Pachuca. Numerous other one to four-day special trips at reasonable prices ($2.90 to $68.50) have been arranged by Aguirre. A folder describing them and many other features of the meeting, will be mailed to all AIME members in North America early in September. This will include a list of hotels and rates for those who do not desire to secure their rooms, tickets, and other services through Aguirre at the overall "package" price.

O'Neill To Be Speaker At WAAIME Annual Dinner

The Annual Dinner of the Womans Auxiliary of the AIME will be held on Wednesday, October 17, 1951, at the Columbia University Club, 4 West 43rd St., 6:30 PM—$5.00 per person. John Joseph O'Neill is the speaker and he is the Science Editor of the *New York Herald Tribune*. He received a Pulitzer award for journalism from Columbia University in 1937. He is an author of books and a contributor to scientific journals. His subject will be, "Science Looks at Tomorrow".

W. D. BARLOW

C. S. T. FARISH

J. R. JACOBSEN

Wallace D. Barlow, formerly a professional staff member of the Interior Committee of the U. S. Senate, is now an industrial engineer with the Executive Office of the Secretary of the Navy. He is located in the Main Navy Bldg., Washington, D. C. Mr. Barlow is working for the Office of Naval Material in the field of nonferrous metals and nonmetallic minerals.

Lloyd E. Antonides has joined the Warren Foundry & Pipe Corp., Dover, N. J. as operation engineer.

Frank C. Appleyard, production engineer, U. S. Gypsum Co., has been transferred from the Chicago office to the plant at Hillsborough, New Brunswick, Canada.

H. S. Berube, formerly assistant superintendent for Republic Steel Corp., Mineville, N. Y., is now assistant manager for East Sullivan Mines, Ltd., Val D'Or, Que.

Charles S. Blair, Black Diamond Coal Mining Co., Birmingham, has been elected president. Mr. Blair was vice-president of the same firm.

C. S. T. Farish, Cerro de Pasco Copper Corp., Lima, is leaving Peru temporarily and will be located at Denver, Colo. for several months.

R. B. Caples, manager of the Great Falls reduction dept., Anaconda Copper Mining Co., was elected president of the American Zinc Institute.

G. D. Creelman has been promoted to research coordinator by the M. A. Hanna Co. He had been director of research.

Charles H. Dunning has resigned as director of the Arizona State Dept. of Mineral Resources.

Jason E. Everts has accepted a position with the American Smelting & Refining Co., North Port, Wash. He had been employed by the Eimco Corp., Salt Lake City.

Charles G. Evensen is now employed by the Baroid div., National Lead Co., Alpine, Texas.

Edward Frohling, formerly with Climax Molybdenum Co., Climax, Colo. is now with the Western Machinery Co., New York.

John R. Jacobsen has joined the Wilson Exploration Co., Los Angeles, as a geologist.

Edward George Fox has been elected to the post of president of the Philadelphia & Reading Coal & Iron Co.

Thomas James Fagan has accepted a position with the San Luis Mining Co., Tayoltita Dgo. Mexico.

George A. Golson is now with the Joy Sullivan Machinery Co., S. A., Mexico.

John Anthony Griswold has joined the National Supply Co., Casper, Wyo.

William A. Griffith is now sales engineer for the Eimco Corp., Kellogg, Idaho.

C. W. Hall, formerly vice-president and general manager of the United Clay Mines Corp., Trenton, N. J. has become president, succeeding the late **George C. Crossley.**

Charles R. Hubbard has accepted a position as mine superintendent and **Joseph J. Kasevniak** as mill superintendent with the Calmet Co., Noumea, New Caledonia.

K. E. Hamblen, consulting engineer, Portland, Ore., is with the office of the Secretary, Dept. of the Interior, and has been working on special assignments connected with minerals and metals.

R. F. Hockey, general superintendent of mines and quarries, B. H. P. Co., Ltd., has been selected as the 1950 recipient of the Australasian Institute of Mining and Metallurgy bronze medal.

Charles D. Hoyt has accepted a position as a trainee for sales engineering with the Goodman Mfg. Co. After the trainee period he will be assigned to a sales district.

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R. Herbert Knapp has been made chief mining engineer, coal div., U. S. Steel Co.

Samuel G. Lasky has been appointed special consultant to the President's Materials Policy Commission. Prior to the appointment he was chief of the Mineral Resources Section, U. S. Geological Survey.

David H. Miller is now engaged in fluorspar mining in the Illinois-Kentucky field.

Robert N. Millar is now in England before taking up an appointment with the British General Electric Co. in Australia.

J. S. Mitchell has been promoted to mill superintendent at the Chelan Div., Howe Sound Co.

James L. Minahan has resigned from the U. S. Geological Survey, Thermopolis, Wyo. to enter into practice as a consulting geological engineer.

F. G. Pardee has become state geologist and chief of the geological survey div., Dept. of Conservation. He had been chief, iron ore section, Defense Minerals Administration.

Guy Riddell has returned to Royal Oak, Md. after making lode and placer examinations in Nevada, Arizona, and California.

Allan S. Richardson, chief ventilation and industrial hygiene engineer, Anaconda Copper Mining Co., has been awarded a distinguished achievement medal by the Colorado School of Mines, Golden.

Stanley Rothschild is now a graduate trainee with Allis-Chalmers Mfg. Co., Milwaukee.

Harry A. Strain has retired as director of raw materials fuel and power for U. S. Steel Co., Pittsburgh. He had joined the company in 1906.

Thomas C. Sersen has accepted a position as junior geologist with the International Smelting & Refining Corp., Salt Lake City.

Harold N. Underhill has resigned as associate editor of MINING ENGINEERING to join the industrial and public relations department of the American Can Co. as an editor of *Canco*, the company's employee publication. Mr. Underhill has been with AIME since February 1949, during which time he also served as associate editor of the JOURNAL OF METALS. He was, in addition, a special feature writer for the *Canadian Mining Journal*, and for *Mine & Quarry Engineering* in London, and will continue writing his "New York Letter" and "American Notebook" for those publications.

J. R. Woodul, vice-president of American Smelting & Refining Co., has retired from active duty with the company. He will, however, remain as a consultant on Latin American affairs.

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Test proves that Marcy Grates will give us at least 22% more tonnage and save us 18% in power along with a reduction in steel consumption. Flotation section prefers the finer grind.
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Obituaries

George Hall Ashley (Member 1899), retired state geologist of Pennsylvania, died on May 28, 1951. Mr. Ashley was born on Aug. 9, 1866 at Rochester, N. Y., and graduated from Cornell University. He received his M.E. in 1890 and his A.M. in 1892. In 1894 he obtained the degree of Ph.D. from Stanford University. Following graduation he became an assistant geologist with the Geological Survey of Arkansas. Later he taught in California for two years and was then assistant state geologist of Indiana. For several years he was professor of biology and geology at College of Charleston, S. C. He then joined the United States Geological Survey. In 1916 Mr. Ashley was acting professor of geology at Vanderbilt University and in 1919 was made state geologist of Pennsylvania. In 1937 he received the degree of Sc.D. from Lehigh University.

Cecil Eugene Bales (Member 1936), president of Ironton Fire Brick Co., Ironton, Ohio, died on May 26, 1951. Mr. Bales was born at Livingston, Ky. on Oct. 23, 1897. He attended

both the University of Chicago and University of Kentucky. In 1920 he joined the Louisville Fire Brick Works, Louisville, as chief chemist. He was promoted to the position of assistant manager in 1926. During this time he was field assistant for the Kentucky Geological Survey on a part-time basis. He resigned from the Louisville firm and became production manager for the Ironton Fire Brick Co. In 1929 he was elected vice-president and later president. Mr. Bales was an active member of various technical societies.

F. Lynwood Garrison (Member 1883) died at Philadelphia on June 10. Mr. Garrison was born at Philadelphia in 1862. He received his education at Rittenhouse and Rugby Academies. He attended the University of Pennsylvania and received his B.S. in 1883 and then attended the Royal School of Mines of London, England for one year. He went to Russia in 1887 investigating methods of making iron and in 1889 was commissioner of the Paris Exposition. He practiced his profession in the United States, Alaska, Canada, and China. From 1902 to 1904 he was chief engineer, Empire Lumber & Mining Co., Tenn. Later he returned to consulting work both here and abroad.

Kenneth V. Haig (Member 1944) was killed in an automobile accident on Mar. 27, 1951. Mr. Haig was born in London on Mar. 25, 1921. He attended Birkbeck College and graduated from the Royal School of Mines in 1943. Following graduation he joined Henry Wiggin & Co., Ltd., Birmingham, as technical assistant. In 1948 he resigned to accept a position on the technical supervision staff with J. H. Enthoven & Sons. At the time of his death he was employed by this firm.

Howard Palmer (Member 1928) has died. Mr. Palmer was a Rocky Mountain member and had been residing at Westerly, R. I.

Eugene P. Shove (Member 1928), Rocky Mountain member, has died. Mr. Shove had been living at Colorado Springs, Colo.

William R. Tonkin (Member 1928) has died. Mr. Tonkin had been located at Vancouver, B. C. and then moved to Southworth, Wash.

NECROLOGY

Date Elected	Name	Date of Death
1943	Henry B. Harriman	June 13, 1950
1912	S. B. Patterson, Jr.	Unknown
1916	W. H. Whittier	June 6, 1951

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Coming Events

Sept. 13-15, AIME, Industrial Minerals Div., fall meeting, University of West Virginia, Morgantown, W. Va.

Sept. 16-19, American Institute of Chemical Engineers, regional meeting, Sheraton Hotel, Rochester, N. Y.

Sept. 18, AIME, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

Sept. 19, AIME, Carlsbad Potash Section, Riverside Country Club, Carlsbad, N. Mex.

Sept. 20, AIME, Utah Section, Newhouse Hotel, Salt Lake City.

Oct. 10-12, Electrochemical Society, autumn national convention, Hotel Statler, Detroit.

Oct. 11-12, Joint Fuels Conference, AIME, Coal Div. and ASME, Fuel Section, Hotel Roanoke, Roanoke, Va.

Oct. 12, AIME, Eastern Section, Open Hearth Committee, Warwick Hotel, Philadelphia.

Oct. 15-17, AIME, Institute of Metals Div., fall meeting, Detroit-Leland Hotel, Detroit.

Oct. 15-19, National Metal Congress & Exposition, Detroit.

Oct. 19-20, Engineers' Council for Professional Development, annual meeting, Hotel Statler, Boston.

Oct. 22, AIME, Chicago Section, Open Hearth Committee, Phil Schmidt's, Chicago.

Oct. 22-24, American Mining Congress, Metal and Nonmetallic Mining Convention, Biltmore Hotel, Los Angeles.

Oct. 22-27, Societe Francaise de Metallurgie, congress, Paris, France.

Oct. 25-26, AIME, Southern California Section, fall meeting, Los Angeles.

Oct. 29-Nov. 3, AIME, fall meeting, Mexico City.

Oct. 30, AIME, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

Nov. 2, AIME, Pittsburgh Local Section and Open Hearth Local Section annual off-the-record meeting. Wm. Penn Hotel, Pittsburgh.

Nov. 2, Illinois Mining Institute, annual meeting, Hotel Abraham Lincoln, Springfield, Ill.

Dec. 2-5, American Institute of Chemical Engineers, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

Dec. 6-8, AIME, Electric Furnace Steel Conference, William Penn Hotel, Pittsburgh.

Dec. 11, AIME, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

Feb. 18-21, AIME, annual meeting, Hotel Statler, New York.

Mar. 3-7, ASTM, spring meeting and committee week, Hotel Statler, Cleveland.

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In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

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(Continued on page 820)

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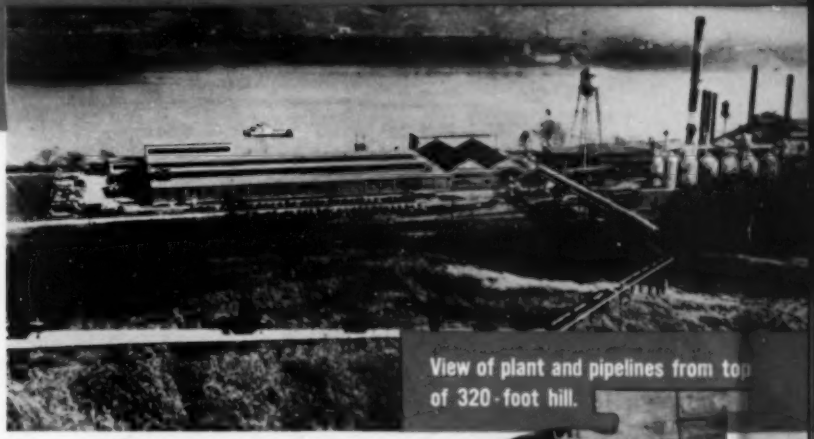

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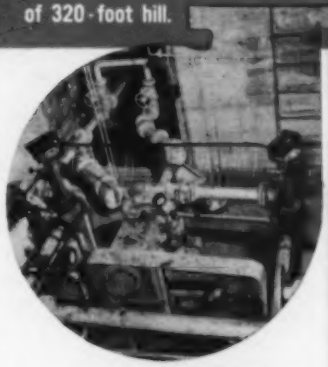

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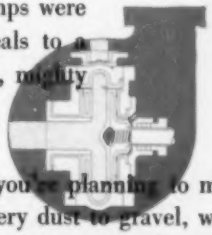

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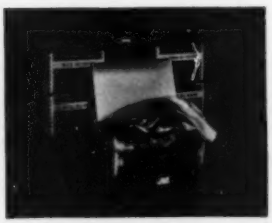
M.S.A. Self-Rescuer

Instant breathing protection for underground emergencies

When deadly after-damp is produced by fire or explosion, the miner's *immediate need* is breathing protection against carbon monoxide. The M.S.A. Self-Rescuer is an approved, dependable safety item that provides the precious minutes of emergency respiratory protection to the miner while traveling from a contaminated area into fresh air. Compact and light in weight, the Rescuer contains a chemical cartridge, hermetically sealed against deterioration. This cartridge is replaceable after use, a feature that makes the Rescuer an economical device for training purposes. The flexible rubber mouthpiece is shaped for a quick, natural fit in the mouth. It forms a perfect seal, assuring inhalation through the Rescuer only. New nose clip design aids wearing comfort. U. S. Bureau of Mines Approved. Write for Bulletin No. BC-1.

For convenient underground storage

The M.S.A. Cache Assembly, consisting of 6 Self-Rescuers complete in a sturdy metal case, permits convenient underground storage throughout the mine. The Assemblies are designed for storage in various locations—working sections, fresh air bases, along belt line, on man-trip cars, for instant application in emergencies. Individual carrying cases also available.



MSA

SAFETY EQUIPMENT HEADQUARTERS

When you have a safety problem, M.S.A. is at your service. Our job is to help you.

MINE SAFETY APPLIANCES COMPANY

Braddock, Thomas and Meade Sts. Pittsburgh 8, Pa.

At your Service: 48 Branch Offices in the United States

MINE SAFETY APPLIANCES CO. OF CANADA LIMITED

Toronto, Montreal, Calgary, Winnipeg, Vancouver, New Glasgow, N.S.

Representatives in Principal Cities in Mexico, Central and South America—Cable Address: "Minsaf" Pittsburgh